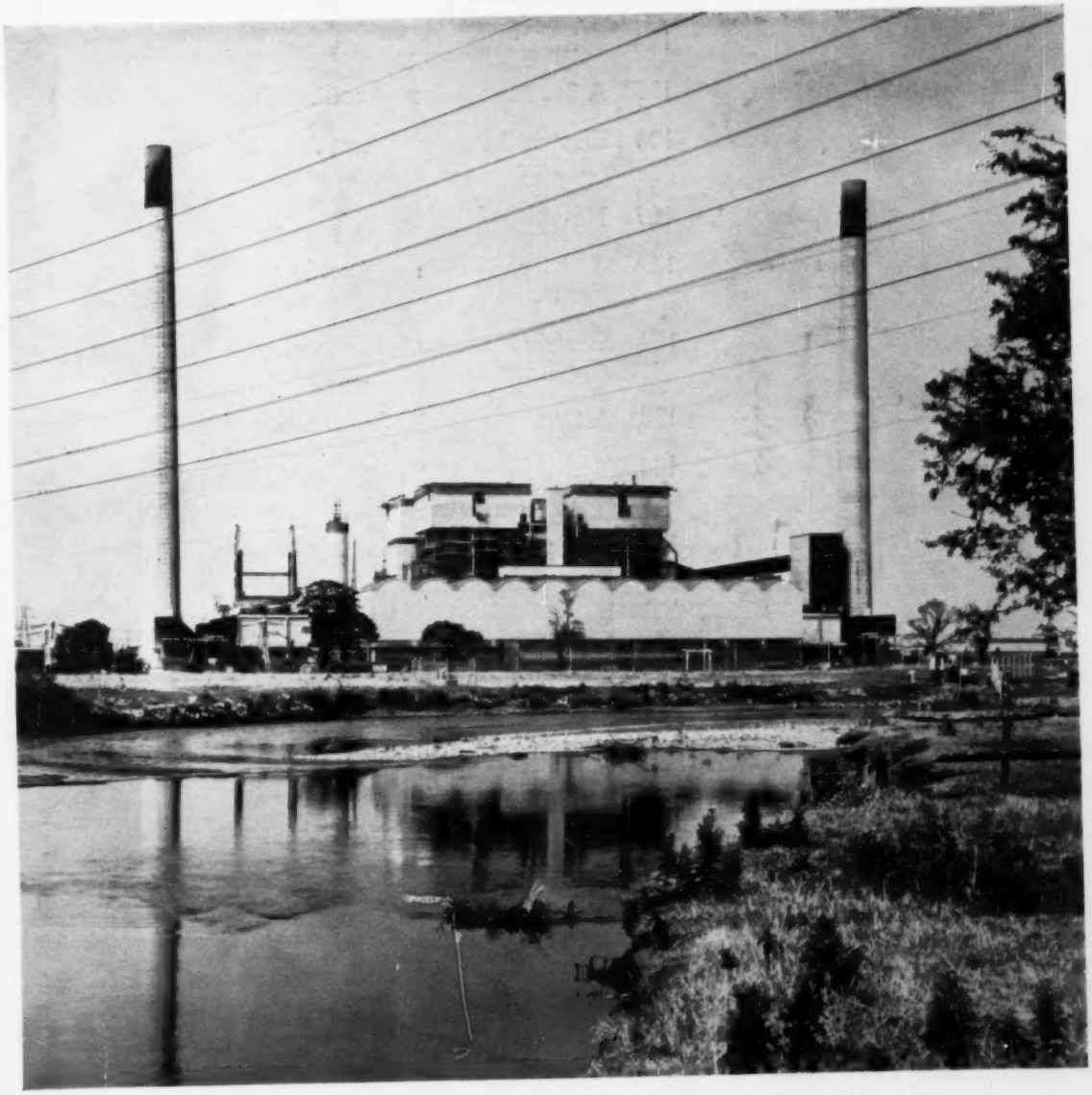
THE BEAMA JOURNAL

NOVEMBER 1959



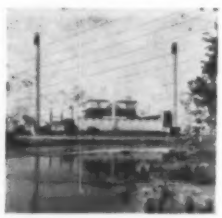
The New Willington A Power Station

A QUARTERLY REVIEW OF
BRITISH ELECTRICAL AND ALLIED ENGINEERING

Special Feature in this issue: Industrial Heating

Contents

	121	Editorial Progress and New Techniques in Generation; Sir Leslie Gamage; 21st Anniversary of ASTA; Industrial Heating
	123	An Unconventional Power Station
	124	British 'Autoland' System at SBAC Show
	125	A 2·6 MW Silicon Rectifier Equipment
	126	Electrical Power System for New British Jet Airliner
	127	Notes
F S Leigh and J B Ingall	129	Bulk Production of Steel in Electric Arc Furnaces
R O'Donoghue	134	Electric Resistance Furnaces and Their Applications
K L Moon	138	A Survey of Induction Heating
Christopher E Tibbs, MIEE	144	Radio Frequency Heating in the Plastics Industry
J Pound, MIRE, AMIEE	148	Radio Frequency Heating in Wood Gluing
	151	Annual Report of the ERA
	152	Japan's First Nuclear Power Station
	154	New Equipment and Processes
	156	Book Reviews
	158	Index to Advertisers



Cover Illustration. *A view of the recently opened Willington A power station taken from across the River Trent, which supplies the station's cooling water. The semi-outdoor type of construction is well shown in this picture. A description of the chief features of the station appears on page 123 of this issue.*

Editor: **Sam Black** *Technical Editor:* **John Dyer**

Published by The British Electrical and Allied Manufacturers' Association (Incorporated), 36 Kingsway, London, WC2. *Telephone:* HOLborn 0502. *Telegrams:* Perisirius, Westcent, London.

Annual subscription: 10/- post free. Single copies, 2/6. Advertising rates on application. Publication dates: February, May, August, and November.

The Association does not necessarily endorse statements made in the Journal.

THE BEAMA JOURNAL

A QUARTERLY REVIEW OF BRITISH ELECTRICAL AND ALLIED ENGINEERING

Volume 66 : Number 4 : November 1959

Progress and New Techniques in Generation

The publication recently of the first annual reports of the Electricity Council and the Central Electricity Generating Board provides a timely opportunity for a review of the progress of electricity generation and supply in Great Britain.

It will be recalled that the Electricity Council came into being on 1 January 1958 and took over part of the functions of the earlier Central Electricity Board which had operated since 1948. The Electricity Council provides the forum for central consultation on, and the formulation of, general policy for the electricity supply industry in England and Wales. Responsibility for the generation and distribution of electricity is now vested in the Central Electricity Generating Board, which works within the framework of the general policy laid down by the Council.

The keynote of both reports is one of continued expansion. The total number of consumers in England and Wales increased by 2·1 per cent over the previous year (1957/58), and sales of electricity amounted to 78 098 million units—an increase of 7·5 per cent.

The average unit price of electricity to consumers was 1·554d—only marginally higher than the figure of 1·533d per unit in the previous year. Several factors have contributed to this successful result: new and more efficient generating equipment, improved forms of organisation, and the continued increase in the scale of operations, and the reports show that the net result of technical and associated improvements is that electricity is being sold today at not more than 36 per cent above the average price per unit ten years ago.

The programme of new generating plant in hand at the end of March 1959 will provide for a net output capacity by the end of 1964 of more than 33 600 MW, of which about 90 per cent of the units then generated will be from conventional plant (mostly coal fired) and some 10 per cent from nuclear plant.

The publication of these reports lends particular significance to other developments reported elsewhere in this issue. On several occasions in the past we have recorded the spectacular advances in the size and efficiency of generating equipment supplied by British manufacturers which have made such an important contribution to the low cost of electricity in Britain.

The latest generating station to be officially opened in this country—Willington A—provides a notable instance of the trend of generating progress, and two unusual aspects of this station's design and construction are emphasised in the description on page 123. Building materials and costs have been appreciably reduced by the semi-outdoor construction adopted, while on the electrical side the new hydrogen pressure cooled alternator installed in the No 2 unit is a significant departure in design trends.

Its importance lies not so much in the machine's output as in the possibilities it foreshadows of increasing the power/weight ratio of future generators, and thereby helping to solve the ever-pressing problem of transporting the large indivisible loads represented by large alternator stators and rotors from their factories to generating sites in this country or to the seaports for shipment overseas.

Previously it seemed as if these transport difficulties would limit the rating of the tandem generating unit as a whole to somewhere about 100 MW, but the direct hydrogen cooling technique promises the possibility of building and moving within the existing transport limitations generators with one-piece stators having outputs even greater than the 200 MW unit which has just started generating at the High Marnham station.

As we have noted in earlier issues of THE BEAMA JOURNAL, the CEGB's policy is to reduce generating costs by steadily increasing the ratings of generating equipment. The 100 MW unit is considered to be the optimum size for non-reheat machines in this country and so represents a transitional stage between the established 60 MW units and reheat machines now programmed as standard units up to 275 MW, with even larger machines scheduled for the future.

Tribute to the important contributions made by the British electrical manufacturers in the way of research and technological advances in generating and transmission equipment is paid by both the Electricity Council and the Central Electricity Generating Board in their respective reports.

Sir Leslie Gamage

The Federation of British Industries has recently announced the formation of a new body — the Export Promotion Policy Committee of the Federation of British Industries — which is to replace the former FBI Export Trade promotion Committee. Sir Leslie Gamage, MC, MA, FCIS, President of The BEAMA, has been elected Chairman of the new Committee.

Sir Leslie Gamage, MC, MA, FCIS

The main tasks of the new committee will be to advise the FBI Grand Council on (i) the programme of future British Trade Fairs overseas; (ii) policy as to UK participation in international exhibitions and trade fairs, and (iii) other promotional activities such as British Trade Weeks, special publicity campaigns, overseas trade missions and so on.

Export promotion is a subject in which Sir Leslie, who for 15 years was President of the Institute of Export, has always taken a very keen and active interest. Under his Chairmanship the new Committee will have a well-informed outlook and a dynamic approach to these important events in the commercial calendar.

Twenty-first Anniversary of ASTA

This year the Association of Short Circuit Testing Authorities completes the first 21 years of its corporate existence. It was formed in 1938 primarily to fill the need for a responsible body which could coordinate tests and testing methods for circuit breakers at the separately owned testing stations, and to provide reports of performance and issue certificates of rating that would be nationally recognised.

Consisting originally of seven member companies operating four short-circuit testing stations, the membership has increased over the years to eleven companies operating eight testing stations, of which seven are specially equipped for testing large circuit breakers, reactors, transformers and fuses, and the eighth specialises in testing fuses only. ASTA has progressively grown into a unique organisation which now includes some of the largest testing stations of their kind in the world.

Almost from its inception ASTA has been recognised as the authoritative body, under the routine supervision of the National Physical Laboratory, for testing and certification of electrical equipment, and a strict adherence to the highest technical standards in performance and methods of testing as laid down by the appropriate British or other standards and the Association's own rules has conferred on the ASTA Certificate of Rating the status of international recognition, and its possession is usually the pre-requisite of orders placed by supply authorities both in the UK and in countries abroad.

The Association is an outstanding example of the advantages that can be achieved by cooperation between manufacturers, since the results of its work have extended far and wide outside the circle of its members and have brought considerable benefits to other manufacturers, to the electricity supply industry, and indeed to buyers and users of electrical equipment both at home and overseas.

Industrial Heating

This issue of THE BEAMA JOURNAL contains the second of the special features announced in our last issue. The subject is Industrial Heating—already a very wide field, and one which is expanding every year as its techniques extend to more and more industries and processes.

It has in fact already wrought considerable changes in many major industries ranging from steel melting and forging to the fabrication of plastic rainwear, and these and other applications are discussed in detail in articles by specialist contributors in this issue. It should be emphasised, however, that these articles are representative rather than exhaustive; they cover as many aspects of this extensive subject as could be accommodated in one issue of THE BEAMA JOURNAL. Furthermore, although the authors are dealing with developments in specific fields of industrial heating with which they or their firms are chiefly identified, the articles should be regarded as typical of British practice as a whole and of the substantial contributions which BEAMA member-firms have made and are making to techniques which are revolutionising manufacturing processes, increasing output, reducing costs and improving the product.

The two BEAMA Sections covering this field and the names of the member-firms are as follows, and the articles mentioned above (which appear on pages 129 to 151) were arranged in consultation with these Sections.

Electric Resistance Furnace Section

Birlec Ltd
Electric Resistance Furnace Co Ltd
GWB Furnaces Ltd
General Electric Co Ltd, The
Wild-Barfield Electric Furnaces Ltd

Industrial High Frequency Heating Equipment Section

Associated Electrical Industries Ltd
Birlec-Efco (Melting) Ltd
English Electric Co Ltd, The
Garringtons Ltd
Lancashire Dynamo Electronic Products Ltd
Peart, E, & Co (Electronics) Ltd
Philips Electrical Ltd
Pye Process Heating
Radio Heaters Ltd
Redifon Ltd
Standard Telephones & Cables Ltd
Wild-Barfield Electric Furnaces Ltd

An Unconventional Power Station

OFFICIALLY opened on 2 October, 1959, Willington A is the newest of the Central Electricity Generating Board's stations and one that departs from conventional practice in two major features to be described later. It has an output capacity of 400 MW produced by four coal-fired boilers of 830 000 lb/hr (376 500 kg/hr) evaporation supplying four 100 MW turbogenerators operating at 1500 lb/in² (105·5 kg/cm²) pressure.

The photograph on the front cover of this issue reveals one of the unusual features of the station: the semi-outdoor construction of the four boiler units and their arrangement in square formation with a central mill aisle and coal bunkers. Two separate turbine halls, each housing two 100 MW sets, are situated on opposite sides of the boiler block, with plant control rooms located between each pair of boiler/turbine units to give fully centralised control, and switch-gear rooms located centrally between each boiler and turbine to give short runs of instrument leads and cables to auxiliary plant.

Constructional Details

The boilers are enclosed only to the degree required for the protection of the operating staff and the protection of drum fittings and mountings against frost. The buildings around the enclosed parts of the boilers and associated plant are steel framed and clad with aluminium 'Alochromed' sheeting and glass above brick plinth walls. The boilers and air heaters are exposed above the 67 ft (20·4 m) and 32 ft (9·7 m) high levels respectively, except for the aluminium and glass box covers over the tops of the boilers.

The two turbine halls (one of which can be seen in the front cover picture) are reinforced concrete framed structures clad with lightweight concrete barrel-vault roofs and aluminium 'Alochromed' sheeting and glass above 22 ft (6·7) m high brick plinth walls.

The unusual design of the station and the constructional methods used have resulted in a compact layout giving an enclosed volume of approximately 19·5 cu ft (0·55m³) per kW installed and a total structural steel usage of 13 tons per MW of plant installed—figures which are low when compared with other stations of similar generating capacity in Britain.

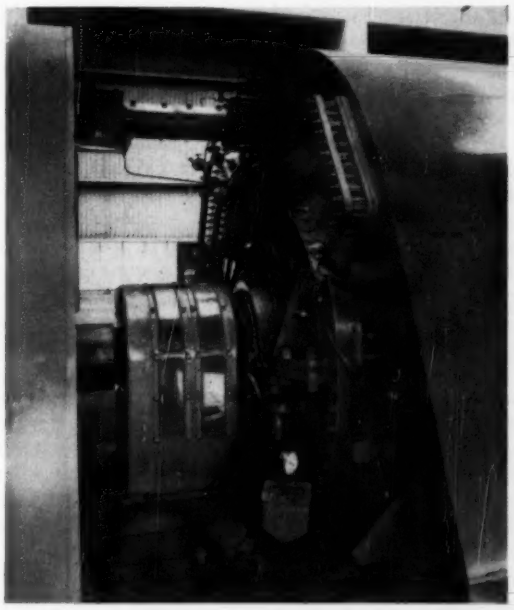
Of the four English Electric turboalternators, Nos. 1, 3 and 4 are of conventional design. The turbines are of the tandem three-cylinder impulse reaction type; the high pressure and intermediate pressure turbines are single flow with impulse blading, and the low pressure turbine is of the double flow type with impulse blading for the first stage and reaction blading for the remaining stages. They run at 3000 rev/min and are designed for steam conditions at the stop valves of 1500 lb/in² (105·5 kg/cm²) and 1050 deg F (565·6 deg C).

Generators 1 and 3 have a generating voltage of 13·8 kV and a rating of 100 MW at 0·8 power factor when operating at a hydrogen pressure of 0·5 lb/in² (35 g/cm²) above atmosphere. They are switched directly at 132 kV. No. 4 generator is identical with Nos 1 and 3 except that it is switched directly at 275 kV. The design power factor at full load rating when operating at a similar hydrogen pressure is 0·9.

The Hydrogen Cooled Generator

No. 2 generator, which is also switched directly at 275 kV, represents the major departure from conventional design and gives Willington A the distinction of being the first station to use the English Electric's fully direct hydrogen-cooled alternator. With over a year's satisfactory and trouble-free running, Willington has provided the proving ground for this outstanding development in design, which is now being adopted for machines of much larger rating.

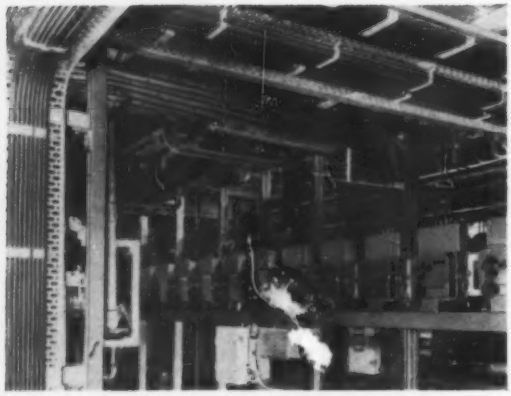
No. 2 has been installed to provide early operating experience of the new cooling technique, and although it is of the same physical size as the other three generators,



A view of No. 2 turboalternator showing the special fan drive modification for the direct hydrogen cooling

the objective of direct hydrogen cooling is the provision of more power from a given size and weight of machine.

The hydrogen gas is circulated at a pressure of 30 lb/in² (2·1 kg/cm²) through channels adjacent to the stator conductors and through the hollow conductors of the rotor by a high speed axial blower of gas turbine design mounted in the upper part of the stator frame and gear



The mezzanine floor at Willington A, showing the cabling to the unit control panels and control desk. For the whole station, nearly half a million yards (450 km) of cable were supplied and installed by Johnson and Phillips Ltd

driven from the exciter gearbox. With this technique it has proved possible to increase very considerably the output of a generator without increasing the overall size and weight, and one-piece stators of much greater output than that of the 200 MW unit at High Marnham can now be built and moved within the existing transport limitations.

Willington A feeds direct to the 132 kV grid and the 275 kV super-grid. Generators 1 and 3 are connected by 120 MVA 13·8/145 kV transformers to the 132 kV switchgear, and generators 2 and 4 are connected by 106 MVA 13·8/295 kV transformers to the 275 kV system.

A second station—Willington B—is now being built alongside the A station and will have the same output, but thanks to the rapid technological advances in electricity generation, only two turboalternators will be required to give the 400 MW now supplied by the four sets in the A station.

British 'Autoland' System at SBAC Show

ONE of the year's most outstanding and significant achievements in aviation is the fully-automatic landing system perfected at the Ministry of Supply's Blind Landing Experimental Unit and shown with great effect at the Flying Display and Exhibition at Farnborough organised every September by the Society of British Aircraft Constructors, this year's event being the twentieth of the series.

The successful 'autoland' or 'hands off' landing system is a joint effort by the electrical and electronics industries and the Ministry of Supply and is the first of its kind in the world. So efficient and reliable is the system that over 4000 automatic landings have now been made with both jet and piston-engined aircraft in weather ranging from high winds to dense fog and from heavy rain to blinding sunlight, and none of the aircraft used by the Blind Landing Experimental Unit has been damaged.

Three companies—Murphy Radio Ltd, Smiths Aviation Division, and Standard Telephones and Cables Ltd—have cooperated with the Ministry of Supply in developing the system, which comprises two leader cables (Murphy Radio) laid one on each side of the runway and the approach path. Magnetic fields from these cables are picked up and fed to the automatic pilot (Smiths) which keeps the aircraft on the centre line of the runway.

The aircraft approaches the aerodrome on a standard instrument landing system, signals from which control the autopilot. A highly accurate radio altimeter (STC) measures the height of the aircraft above the runway from 60 ft (18 m) and causes the autopilot and automatic throttle control to check the rate of descent and begin the flare-out from the approach path to the touch-down. Cross-winds are automatically countered and after touch-down signals from the leader cables can be used to keep the aircraft straight on the runway.

Examples of the equipment used in the system were shown by the MoS and the three firms concerned.

Murphy Radio Ltd featured a complete leader cable system, including the aircraft and ground units which provide the azimuth guidance.

Smiths Aviation Division showed pictorially the phases of automatic landing as well as the SEP 2 autopilot gyro unit used in the aircraft and the Smiths Flight System used for visual monitoring of the automatic landing.

Standard Telephones and Cables Ltd showed the remarkable radio altimeter which is the heart of the system. This is the instrument which takes control when the aircraft has descended to 60 ft (18 m) and feeds information to the autopilot to complete the landing manœuvre in an exponential flare-out curve.

In this design, STC have produced the first altimeter of its kind in the world and so far no similar instrument has been produced in any other country. Operating on a frequency-modulated signal, it can accurately measure heights down to 1 ft (30 cm), and its outstanding performance is to be accepted as a world standard.

The instrument landing system used throughout the tests uses constant automatic monitoring of the ILS beam to maintain its accuracy, and at a range of 1000 ft (305 m) it gives an error not exceeding $\pm$ 8 ft (2·4 m) from the centre of the runway.

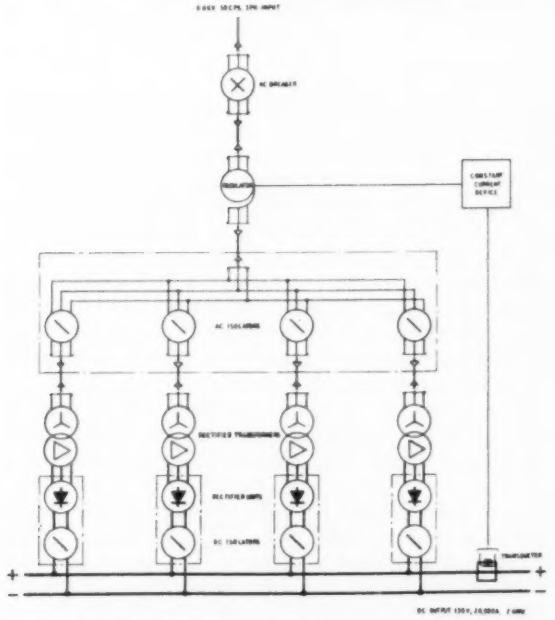
Further developments of the system are now aimed at reducing its cost, which is between £50 000 and £80 000 in its present form, but it is hoped to reduce this substantially, and possibly even to halve it. As one instance, improvements in instrument landing techniques suggest that the leader cables now buried in the ground on each side of the runway and approach path may eventually be replaced by highly-stabilised radio beams.

The exhibition as a whole serves to emphasise aviation's increasing dependence on its electrical and electronic equipment, and current figures indicate that the requirements of modern civil airlines for navigation, communications, passenger comfort and safety amount to at least 20 per cent of the total cost. In military aircraft the proportion is very much greater.

A 2·6 MW Silicon Rectifier Equipment

AMONG the firms in the United Kingdom who have been actively engaged for some years in research and development work on semiconductors are Standard Telephones and Cables Ltd, and the spacious modern factory of the Rectifier Division at Harlow in Essex is now fully occupied with the large-scale commercial production of a wide range of semiconductor devices from television diodes to compact and robust silicon rectifiers with high output capabilities.

One type in particular, with a continuous rating of 100 A, a surge rating of 1000 A and capable of operating at 300 peak inverse volts, has now reached an advanced stage of application where it is possible to employ them in large numbers in high power ac to dc conversion equipment, so giving installations of high electrical efficiency with relatively small area requirements.



The general circuit arrangement of the 2·6 MW silicon rectifier equipment described in this article

Such an application is the 2·6 MW silicon rectifier equipment which we recently had an opportunity of inspecting, and which is to be installed in the plant of the Electrotype Metals Corporation in the Transvaal, South Africa, for the electrolytic production of manganese.

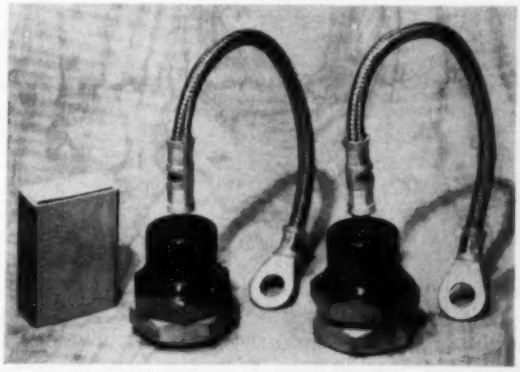
The small size of these silicon rectifiers has made it possible for the whole of the equipment, with the exception of the ac circuit breaker and the regulator, to be contained in one room measuring only 50 ft by 20 ft (15·3 m by 6·1 m). This room accommodates the rectifier transformers, the rectifier cubicles and their associated control cubicle, and the oil cooling system. A smaller control panel projects into the electrolytic plant area through the dividing wall, and overhead busbars carry the load current of 20 000 A at 130 V to the manganese cells.

As will be seen from the schematic of the general arrangement, a single 3150 kVA regulator controls the entire equipment, which is split into four transformer/rectifier sections. The ac and dc isolators allow the removal of any one section for maintenance purposes, leaving the plant operating at 75 per cent of full load.

The four rectifier cubicles are paralleled on the dc output side and supply the complete power requirement for the electrolytic process. The total output current is maintained to within 2 per cent of any required value between 15 000 and 20 000 A by a constant current control loop to the main input regulator, and the required current setting is made by the plant operator at the control panel in the electrolytic plant area. In addition, the regulator is able to control the output down to 65 V at no load.

Since the equipment is not paralleled with other conversion apparatus liable to give overload conditions (such as a contact rectifier or a mercury arc rectifier under backfire) there is no need for dc circuit-breaker protection. Fault current limitation is provided by the regulator and supply line reactance in conjunction with the built-in reactances of the rectifier transformers. Normal dc overloads are unlikely from the electrolytic process, but protection against such faults is arranged by ac circuit-breaker tripping from current transformers in the ac isolator panel.

Each of the four rectifier cubicles contains two separate three-phase bridge connections of 100 A silicon rectifiers (RS 8 Series), supplied from common ac busbars and feeding via separate isolators into the main 20 000 A busbar. Six hollow aluminium busbars form the arms of each three-phase bridge and provide the cooling, by a circulatory oil system, to the twelve paralleled rectifiers in each arm. In every arm of a cubicle there are thus 24 parallel-operated silicon rectifiers.



Two of the high power silicon rectifiers with a continuous rating of 100 A and a surge rating of 1000 A. Their small size is shown by the matchbox in the photograph

Special high-speed fuses are incorporated to protect each pair of rectifiers. The failure of one fuse in any arm is shown by an indicator lamp; failure of more than one fuse in any one arm initiates a warning system.

The cubicles are fitted with a pyrometer to indicate the busbar temperatures during operation.

The cooling oil from the hollow busbars is circulated by a duplicated oil pump and passes through an oil-to-water heat exchanger, and the water is in turn circulated through a cooling spray pond. The overall operation of the cooling system maintains the oil temperature below 115 deg F (46 deg C), when 6000 gallons (27·27 kl) of oil per hour are cooled by 6 500 gallons (29·54 kl) per hour of water at 86 deg F (30 deg C). Failure of the oil or water coolants off-loads the equipment.

The calculated efficiences are:

Rectifier efficiency:	98·2 per cent at full load
Overall equipment efficiency:	94·6 per cent at full load

Even though the plant losses have been minimised (in particular by the use of grain-oriented transformer cores), the rectifier losses contribute less than one-third of the total.

With the exception of the main ac oil circuit-breaker, all the equipment is being supplied by Standard Telephones and Cables Ltd.

Electrical Power System for New British Jet Airliner

THE electrical power system of the new DH 121 jet air liner, 24 of which are now on order for British European Airways, will be designed and supplied by the Coventry Works of Associated Electrical Industries Ltd—the division of AEI which now incorporates the aircraft activities of the British Thomson-Houston Co Ltd.

It will be recalled that BTH supplied the electrical power equipment for the de Havilland Comet 4 jet aircraft, and a description of its principal features appeared in our May issue*. For the DH 121 a 3-channel constant frequency system has been developed, and particular interest atttaches to the brushless type self-excited alternators (which will be the first British machines of this type to be used in aircraft); the static magnetic amplifier control equipment which makes extensive use of silicon power rectifiers, and the long-life contactor switching equipment. These features all contribute substantially to extending the service period between overhauls to 3000 hours—approximately double that of other systems now in use in civil aircraft.

The 200 V 3 phase constant frequency power supply will be derived from three of the new brushless alternators driven at 8000 rev/min by a hydraulic constant-speed unit, but a feature of the system is that the three alternators will not normally operate in parallel but on a three-channel system, and each alternator will be capable of giving a full output of 2 to 2·5 kVA 400 c/s at 200 V. Provision will be made for switching essential loads in the case of alternator failure, and provision will also be made for parallel operation if considered desirable and to meet all possible future requirements.

The brushless alternator removes one of the major problems—that of brush wear at high altitudes, and bearing life then becomes the limiting factor in determining the periods between overhauls. BTH experience with the Comets has fully proved the value of oil-lubricated alternator bearings, and in the DH 121 system provision is made for oil circulation through the alternator bearings from the hydraulic constant-speed unit.

The operation of radar equipment in aircraft calls for the control to very close limits of the voltage and frequency of the generators, and BTH have pioneered the development of static regulators for this purpose. The latest type employs magnetic instead of electronic amplifiers and offers maximum reliability in use, and its speed of response has now been made comparable with that of electronic equipment. It contains no moving parts, and the introduction of silicon rectifiers and a 'potting' technique for individual components should ensure complete freedom from adverse environmental effects in service.

Each power circuit will incorporate protection against over- or under-voltage, over- or under-frequency, fault current, out-of-balance current and incorrect phase rotation, all applied by static equipment operating the main power contactor. Automatic synchronising circuits will be applied when parallel operation is required.

The distribution system will use more than 200 single, double, and triple pole toggle-type switches with ratings up to 15 A at 200 V, and a similar number of thermal-trip circuit-breakers on single- and three-phase circuits with ratings varying from 1 to 24 A. There will also be about 30 power contactors of both magnetically-held and mechanically-latched types, with ratings from 15 A up to 100 A at 200 V.

Motors in the aircraft will vary from very small 4·5 oz (128 g) sizes for the cooling fans in radar and radio equipment to large continuously-rated motors for driving aircraft equipment, cabin air-circulating fans and so on, the largest being of 8 hp rating for driving hydraulic pumps for ground service and emergency undercarriage retraction.

* THE BEAMA JOURNAL, 66, No 2, pp 47-50

Notes

Britain's Largest Power Station

The Central Electricity Generating Board now has under construction the largest power station yet projected for the British Isles. The site is at Drakelow, near Burton-upon-Trent, and the station will have a total output capacity of approximately 1 500 MW.

Drakelow is on the fringe of the East Midlands coalfield which is a major source of the low-grade coals used for the production of electricity. There is already a 240 MW station on the site—Drakelow A, which was commissioned in 1954, and a second station with a capacity of 480 MW—Drakelow B—is now ready for commissioning. The newest station will be known as Drakelow C.

Drakelow B has four 120 MW generating sets supplied by four boilers of 860 000 lb/hr (390 000 kg/hr) capacity with steam conditions of 1 500 lb/in^2 (105·46 kg/cm^2) and 1 000 deg F (537·8 deg C) with reheat at the same temperature. The first set for Drakelow C is already under construction. It will be a 350 MW unit with a boiler of 2 450 000 lb/hr (1 111 300 kg/hr) steam capacity operating at 2 400 lb/in^2 (168·7 kg/cm^2) and 1055 deg F (568·3 deg C) with reheat at the same temperature. It is scheduled for operation in 1964.

As Drakelow is at a focal point of the 275 kV supergrid, the output of the new station can be fed into the system without the construction of additional overhead transmission lines.

Largest Turboalternator in the Commonwealth

The four 200 MW turboalternators supplied by C A Parsons and Co Ltd for the Richard L Hearn generating station in Toronto are the largest to be exported from England at the present time and the largest yet installed in Canada. The first of these machines has now been in commission for some time, and the installation of the remaining three will bring the total station capacity to 1 200 MW, making it the largest both in Canada and in the world with generating equipment made by the one manufacturer.

The 200 MW machine is of cross-compound design; one line consists of a hp and ip turbine driving a 100 MW hydrogen-cooled generator at 3 600 rev/min. The other line comprises a second ip turbine and lp turbine driving a second 100 MW hydrogen cooled generator at 1 800 rev/min.

Steam conditions are 1 800 lb/in^2 (126·55 kg/cm^2) at the stop valve at 1 000 deg F (537·8 deg C) with reheat between the hp and first ip turbines to the same temperature. The alternators generate at 13·8 kV 60 c/s 0·8 pf. Both are hydrogen cooled with rotors of the direct cooled type operating in hydrogen at 30 lb/in^2 (2·1 kg/cm^2). Excitation is provided by separately-driven exciter units.

Increasing Use of Buried Type Distribution Transformers

The South of Scotland Electricity Board has ordered six buried type distribution transformers from Ferranti Ltd for installation in the Clyde sub-area. The order covers the supply of five 500 kVA and one 1 000 kVA 11 000/433/250 V 3-phase units utilising Class C materials.

This development reflects the increasing interest of electricity authorities in this type of equipment as an answer to the growing problem of system reinforcement. The idea of these buried type units, which have been made possible by the introduction of Class C insulation, was conceived by engineers of the South of Scotland Electricity Board in cooperation with Ferranti Ltd, who recently reported on the successful results of long term field trials carried out on one of these units.*

Their main advantage is that they can be installed without difficulty nearer to a load centre, in contrast to the more conventional solution of reinforcing networks by replacing existing transformers by units of larger rating. In some cases this may leave the supply transformers remote from the new system load centre.

Some Notable Export Orders

Australia

Bruce Peebles and Co Ltd of Edinburgh have now despatched the first two out of an order for three 90 MVA 275/66/11 kV transformers for the Magill Substation, Adelaide, of the Electricity Trust of South Australia. These are the largest transformers so far under construction anywhere for Australia.

Weighing 188 tons when stripped for transport, they were taken by road to Leith Docks and put on board the Norwegian vessel *Belkarin* which is equipped with derricks capable of dealing with weights of that magnitude.

Shipping a 90 MVA 275/66/11 kV transformer at the Scottish port of Leith for its journey to Australia. Two of these transformers have already been despatched; a third follows next year

The transformers will be used to link the main 275 kV line from Port Augusta power station to the metropolitan system in Adelaide. The third transformer is scheduled for despatch next year.

Bruce Peebles and Co Ltd have also recently received confirmation of a second large order from Australia—this one for transformers worth between £300 000 and £400 000 from the State Electricity Commission of Victoria.

The order covers four 30 MVA 3-phase 50 c/s 220/66 kV transformers and seven single-phase transformers to make two 3-phase banks rated at 45 MVA 220/22 kV with a spare single-phase unit. They will be used in the power distribution system of Victoria.

New Zealand

Half the output of the Meremere power station in New Zealand—the first coal burning station in that country—is being supplied by three 30 MW Metropolitan-Vickers turbogenerator sets manufactured by the AEI Turbine Generator Division. Included with the generating equipment were three twin-shell condensing plants with ejectors and extraction pumps and three four-stage feed water-heating equipments.

Other AEI equipment at Meremere includes a turbine gauge-board, a field suppression cubicle, automatic voltage-regulating equipment, a neutral earthing cubicle, all the electric motors for coal handling and oil feed machines, and most of the motors for other drives throughout the station.

Mexico

The British Thomson-Houston Export Co Ltd (now part of Associated Electrical Industries Export Ltd) recently received an order to construct and equip a complete steam power station for the Federal Electricity Commission of Mexico. It is to be in commission early in 1961 and will supply electricity to an area on the Pacific coast.

Standardised designs have been developed by AEI for steam-generated power stations complete with buildings and plant, and although in this case foreign competitors made similar claims, it is understood that the accepted AEI design was nearer completion and capable of construction in the shortest time.

Initially, two 6·25 MW turbine generators will be supplied, operating with steam conditions of 400 lb/in^2 (28·1 kg/cm^2), 752

* THE BEAMA JOURNAL, **66**, No 1, pp 22–23

deg F (401 deg C) and condenser vacuum of 27·5 in (69·85 cm) of mercury. The generators will be rated at 7 812·5 kVA 60 c/s 3-phase 0·8 pf and will generate at 13·8 kV.

All the miscellaneous equipment is included in the contract to complete the initial stage of the power station which is to be constructed to accommodate a third turbogenerator and boiler plant at some future date.

Portugal

A contract has been signed between Siderurgia Nacional SARL and Metropolitan-Vickers Electrical Export Co Ltd (on behalf of AEI) and Babcock and Wilcox Ltd covering a complete power station for a steelworks to be built at Seixal to the south-east of Lisbon. The total value of the contract is approximately £500 000.

This will be the first steel works in Portugal. It is planned to go into commission by the end of 1960 and to produce initially 250 000 tons of raw steel a year, rising to 500 000 tons in 1964.

The power station plant to be supplied by Babcock and Wilcox Ltd includes two 35 tons/hr integral furnace type boilers fired with blast furnace gas or oil, together with the boiler house equipment. Steam will be supplied at 900 lb/in² (63·28 kg/cm²) 900 deg F (482 deg C) to a 14 MW single cylinder turbogenerator and associated heat exchange equipment supplying power at 6 kV 3-phase 50 c/s. The generating equipment will be manufactured by the AEI Turbine Generator Division.

Argentine

A recent addition to the expanding fleet of diesel-electric locomotives of the Argentine State Railways consists of twenty-one 1 000 hp mixed traffic units from the English Electric Co Ltd which are now entering service on the General Belgrano Railway. They are generally similar to five units supplied to the Buenos Aires Provincial Railway in 1956. Power and transmission components for the new locomotives, which are double bogey metre gauge units, have been made at the English Electric Co's Preston Works, while the mechanical parts are products of the Vulcan Foundry Ltd and Robert Stephenson and Hawthorns Ltd—both members of the English Electric group. All the locomotives have now been shipped.

The Philippines

The capacity of the Republic Cement Corporation plant at Norzagaray, 30 miles (48 km) north of Manila, the most modern in the Philippines, has now been doubled and the complete plant is now in full production. All the electrical equipment for the extension was supplied by the English Electric Co Ltd under a contract worth about $350 000 won against strong international competition. The original plant had an output of 10 000 bags daily; it is now 20 000 bags daily.

The main outdoor substation was extended with a 3 750 kVA 34·4/4·16 kV transformer with a double feed to the main switchroom, which houses an 11-panel 4·16 kV switchboard with a rupturing capacity of 250 MVA at 6·6 kV.

Four panels of the board feed the large motors: two 1 320 hp mill motors, a 460 hp mill fan motor and a 385 hp exhaust fan motor. The other 62 motors, ranging from 0·25 to 140 hp, are fed from a number of 4·16 kV/440 V distribution transformers in the plant. Most of the motors are of the totally enclosed and protected type; drip-proof motors are used where there is a great deal of moisture.

The contract also included the medium voltage switchgear, control equipment and an 82 hp variable speed dc motor for driving the rotary kiln. A drive was specially developed to follow the American practice of housing the Ward Leonard motor generator set and starter within the dc control cubicle.

USA

An order exceeding $250 000 has been placed with Ferranti Ltd by the Anaconda Wire & Cable Company of Hastings-On-Hudson, New York, for what is believed to be the largest high voltage ac cable testing set yet built by a British manufacturer.

The order covers the supply of a 14 000 kVA 250 000 V ac cable testing set capable of supplying 55 A for approximately two hours. A second transformer unit is also included which, when connected in cascade, will give an output of 500 000 V at 6 A continuously.

The equipment will be designed for controlled series resonant operation for both 250 000 and 500 000 V by means of continuously variable moving coil reactors. Two step-up transformers, one feeder transformer, two moving coil reactors and control desk comprise the complete equipment.

Recently Ferranti Ltd supplied to Anaconda a 300 000 V, 2 400 kVA testing equipment for research and development work; the new and much larger equipment is intended for routine testing of cables.

Japan

The Westinghouse Brake and Signal Co Ltd have received through the Electro-Chemical Engineering Co Ltd an order for Japan which will include Westinghouse water-cooled selenium rectifiers to provide 60 000 A to be used for electroplating a protective coating of zinc on steel sheets.

The principle has been widely employed in Britain; other plants are in operation in Belgium and a plant has just been commissioned in France, all of which employ Westinghouse rectifiers.

GEC concludes Nuclear Agreement with MAN

The General Electric Company Ltd of England and Maschinenfabrik Augsburg-Nürnberg AG (MAN) of Germany have recently concluded a long-term nuclear power agreement which is initially for a period of ten years, but is capable of extension.

Under the terms of the agreement MAN will pay the GEC a capital sum plus a service fee per kW of guaranteed electrical output from nuclear power stations ordered from MAN. The German company will be granted licences for all GEC nuclear patents, and similarly any inventions which MAN may make relating to nuclear power plant will be available to the GEC organisation.

The new agreement, however, is much more than a licensing arrangement. The whole of the knowledge and experience accumulated by GEC and its British collaborator Simon-Carves Ltd in the design and construction of nuclear power plant will be made available to the German company.

The traffic in knowledge and facilities will not, of course, be one-way. MAN is one of Germany's largest engineering firms manufacturing a very wide range of engineering equipment, and the German company's extensive experience in heavy steel fabrication will be of particular value in nuclear work. MAN has already been concerned with mechanical engineering aspects of research reactor projects in Germany.

During the first stage of the agreement, GEC will normally act as main contractor for all nuclear orders received. The ultimate aim, however, is that MAN shall itself become competent to prepare tenders and to execute complete contracts to designs resulting from collaboration. To this end, GEC experts will advise and assist the German organisation in setting up the necessary facilities, while MAN key personnel will receive special training in the United Kingdom to equip them for full participation in this rapidly developing field of technology.

'Merlin' Reactor on Test

Britain's first privately owned research reactor 'Merlin' is now on its proving trials at the research laboratory of Associated Electrical Industries Ltd at Aldermaston in Berkshire. It has been built by the AEI-John Thompson Nuclear Energy Company, who are also building the nuclear power station at Berkeley for the CEGB.

'Merlin', which has cost about £600 000, is a water cooled, water moderated reactor using uranium 235 as fuel and will be used for research, testing, education, and the training of nuclear physicists and engineers. It was originally designed as a 1 MW reactor but has now been redesigned and its power raised to 5 MW, partly to meet the demand from overseas for a higher powered reactor and partly to increase the available testing facilities in the United Kingdom.

The company has received orders for two similar reactors—one from Nordrhein-Westfalen in Western Germany and one from the Atomic Weapons Research Establishment (AWRE) of the UK Atomic Energy Authority at Aldermaston. It is reported that South Africa is also interested in a similar purchase.

Sixth Nuclear Power Station Approved

Consent has now been given by the Minister of Power for the construction of a new nuclear power station at Dungeness, on the south-east corner of the English coast. This will be the sixth station in the current nuclear programme. The new station will have a capacity of 500–550 MW, but it is stated that the site would be capable of development up to 1 500 MW.

Bulk Production of Steel in Electric Arc Furnaces

*F S Leigh and J B Ingall**

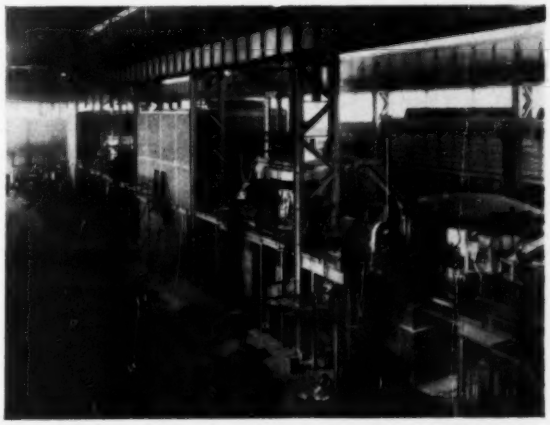
THE last twelve months have seen an important development in the British steel industry in the matter of the bulk production of steel in arc furnaces. The first arc furnace for the production of steel on a commercial basis was installed in Britain in 1910. The first world war gave an impetus to production of alloy steels in this type of equipment and in the period between the wars there was a steady rise in arc furnace steel production. There was also a marked increase in the production of electric steel during the second world war and in 1948 the total production of electric steel was approximately 0·75 million tons a year.

Virtually the whole of this output was for alloy steels or for foundry use, because from its inception the arc furnace was appreciated for the production of steels demanding high purity and exacting analysis. The arc furnace is probably the most versatile steel making equipment available, in that a wide variety of conditions within the furnace can be precisely controlled. The normal two-slag method of manufacturing steels using both an oxidising period and a reducing period illustrates this. During the melting down of scrap metal within the arc furnace, there is an oxidising period giving conditions favourable for the reduction of phosphorus and carbon in the charge. When the phosphorus and carbon have been reduced to the desired level, the oxidising slag is taken off and a reducing slag is formed which enables the sulphur and iron oxide contents of the charge to be reduced. Subsequently any additions can be made enabling a desired specification and analysis to be accurately met. The flexibility and ease of control of the arc furnace have made it the most important tool in alloy steel production.

Two 50 ton arc furnaces installed at Round Oak Steelworks Ltd. Each furnace is 19 ft (5·8 m) in diameter and is rated at 20 000 kVA. In the foreground the ingot moulds can be seen standing in the casting pits

The use of an arc furnace in a foundry comes about for various reasons. Speaking generally, the demand for molten metal in a steel foundry is for relatively small quantities at frequent intervals. The Tropenas converter fulfils this requirement, but refractory and labour costs are appreciably higher than with an arc furnace of similar output. Also, the arc furnace has the advantage of being able to operate on 100 per cent steel scrap which is cheaper than pig iron, whereas the cupola/converter practice requires a proportion of pig iron in the cupola charge.

It can be said therefore that up to 1958, when the total arc furnace production of steel in Britain was approximately 1 250 000 tons per annum, this liquid metal was



A general view of the melting shop at Brymbo Steel Works Ltd, in which the pre-refining vessel is shown in the right foreground and three 40 ton arc furnaces spaced at intervals down the shop. Each furnace is 16 ft (4·9 m) in diameter and is rated at 12 500 kVA

used either for alloy steel ingots or for foundries. However, in the last twelve months there have been commissioned in this country two important electric arc melting installations which will increase the yearly production by approximately 500 000 tons per annum. This additional output of arc furnace steel will be principally plain carbon steels of the type which hitherto have been produced in open hearth furnaces.

It is interesting to consider why this development has arisen and to appreciate that it is a beginning of a trend which may well lead to a considerable increase in this country's output of electrically produced steel. Some years ago, a careful study of the relative economics of producing bulk steel in arc furnaces was made by the Batelle Memorial Institute of America. Although this study was based on American practice, it was read with wide interest in the UK because it had already been realised that the production costs of open hearth steel and electric arc furnace steel were becoming more nearly equal.

Probably the most important reason for the introduction of arc furnaces for the production of bulk steels is a very much reduced capital cost. It can be said that the capital cost of an electric furnace shop is approximately two-thirds of the capital cost of an open hearth shop for the same output of bulk steel.

* Birlec-Efco (Melting) Ltd

It is however important to note that where a relatively small output of steel from iron ore is required, of the order of 500 000 tons a year, then it is cheaper to install an arc furnace shop operating in conjunction with some oxygen process, or alternatively one of the new direct reduction processes such as the Strategic-Udy process, rather than a blast furnace and open hearth shop.

The next most important reason why the arc furnace is now better favoured is the relative reduction in the cost of electricity as compared with other forms of fuel. Over the last 20 years the cost of coal delivered to power stations has risen from approximately 19s 6d to £4 1s 0d per ton or 415 per cent, whereas the corresponding rise in the cost of electricity (even though this has been largely derived from coal) has only risen from 1·05d to 1·53d per unit or 46 per cent. (These are, of course, UK figures. In other countries where there is little or no coal but an abundance of hydro-electric power, the comparison is even more favourable.)

There is a further development in the steel industry which will lead to increased production of steel from the electric arc furnace. This is the increasing success of continuous casting—a process consisting of the manufacture of a steel billet direct from molten steel by a continuous solidification process. The demands of a continuous casting machine are best met by an arc furnace, and as this development proceeds more arc furnaces will be installed.

It is perhaps worth while describing briefly the principal features of an arc furnace installation suitable for the tonnage production of steel. Reference is made to Fig 1. The arc furnace itself consists essentially of a refractory-lined steel basin fitted with a removable roof. This basin can be tilted in the forward direction for emptying and in the backward direction for slagging off. Facility is provided in the bricked roof of the furnace for the entry of the three graphite electrodes which are carried by electrode arms which are in turn carried on movable masts. Electrical connexion is made to the electrodes by means of water-cooled bus-tubes carried on the arms and flexible electric cables between the transformer end of the arms to busbars which go directly to the furnace transformer.

In recent years, a great deal of work has been carried out on the problems associated with the electric arc furnace and at the present time there are investigations being carried out by many bodies such as BISRA (the British Iron and Steel Research Association), the Electricity Authorities, the furnace manufacturers, and the transformer and switchgear manufacturers.

The Furnace Refractories

One of the most important charges to be considered in the manufacture of steel in an arc furnace is the cost of refractories, which can amount to approximately £1 per ton. Refractory wear occurs in two main ways: (a) by chemical attack of the metal or its slag, and (b) by the fluxing away of the refractory surface by direct radiation either from the steel or, more seriously, from the arc itself.

BISRA has, after an extensive research programme, developed a system of power control based on refractory temperatures. The normal procedure in melting is to use maximum power (at maximum voltage) during the melting down period when the arcs are buried in the scrap forming the charge. This scrap protects the furnace refractory walls and roof from direct radiation. As the melt proceeds and there is no longer this protective scrap screen because it has melted away, the furnace operator reduces the voltage and the consequent length of the arc in an effort to reduce radiation and consequently reduce refractory wear. It is not an easy matter for the operator to determine when precisely he should reduce his voltage. If he reduces it too soon, then he is unable to obtain the full output of the furnace. If however he is too late in

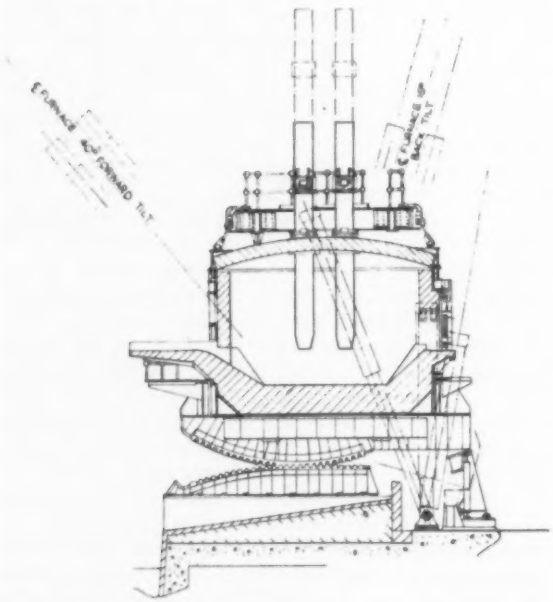


Fig 1. Sectional diagram of a typical arc furnace installation

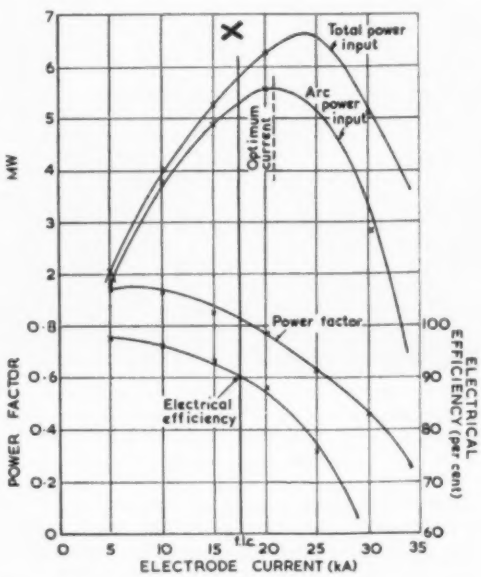


Fig 2. Power input curve for a 7·5 MVA arc furnace

making the reduction, then he will have excessive refractory wear. Briefly the scheme proposed by BISRA is to measure the temperature of the refractories and control the furnace voltage and power from this.

The control part of this system is not difficult, but there have been considerable difficulties in the accurate continuous measurement of roof and side wall temperatures which are of the order of 1 500 to 1 600 deg C.

Both thermocouples and radiation pyrometers have been used. Special thermocouple sheaths have been developed for protecting the thermocouples and these have been encouraging, but greater success has been obtained with a narrow angle radiation pyrometer sighted on the roof or side walls through an aperture in the wall of the furnace.

Graphite Electrodes

The cost of the electrodes can also represent a major item in the production of bulk steel, amounting to something of the order of 15s 0d per ton, and it is very desirable to the industry to reduce this running cost if at all possible. The electrode is consumed in two ways: first by surface oxidation, and second by vaporisation of the graphite at the tip of the electrode where temperatures of the order of 3 000 deg C are achieved. Efforts are being made to try and reduce both these types of loss. It is possible to reduce surface oxidation from the electrode by suitable coatings, but unfortunately the cost of the coatings has hitherto proved more expensive than the electrode which would have oxidised away.

There is not a great deal of knowledge on the fundamental properties of an arc, so investigations are being pursued to determine the properties of an arc in an effort to reduce the temperature at the electrode tip which will in turn reduce the vaporisation losses.

Regulator

There is probably a greater divergence of opinion on the requirements for an arc furnace regulator than on any other part of the arc furnace equipment. There exist two extreme views on the requirements of a regulator and all shades of opinion between them.

One view is that the electrode should have an extremely rapid acceleration and speed of response, coupled with a high ultimate speed. The argument in favour of this type of regulator is that only by this high performance is it possible to reduce the surges and consequent flicker. The total reactance in circuit on an arc furnace installation is of the order of 40 per cent. During the course of a melt it is possible to get a symmetrical short circuit of the system occurring at the electrodes when scrap falls against all three electrodes. There will be smaller but nevertheless serious fluctuations in load occurring almost continuously during the melting period.

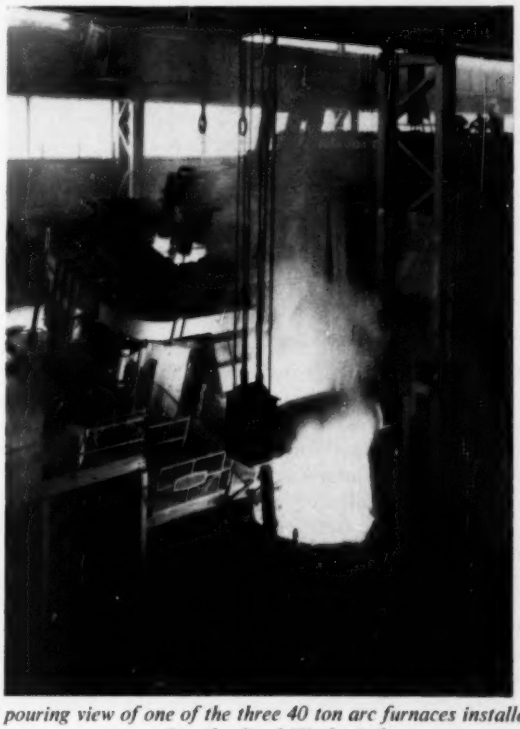
Unfortunately the regulator can only respond to these fluctuations and cannot anticipate them. It is therefore unlikely that any regulator, however fast, will eliminate distribution network disturbances caused by an arc furnace. The most important influence on these disturbances is the strength of the distribution network in terms of its fault level. The higher the fault level, the less would be the effect of a short circuit at the electrodes. It has been generally accepted that the fault level of the system should, if possible, be of the order of 100 to 150 times the rating of the furnace, in order to keep the level of flicker acceptable.

The basic requirements of a regulator are as follows:

(1) Power Consumption should be a Minimum.
Referring to Fig 2, which shows a set of typical operating curves for an arc furnace, the power consumption is kept to a minimum by ensuring that the normal operating current is at or around X, which is less than the optimum current. The regulator should ensure that the fluctuations occurring in the current should be kept below the optimum.

(2) Carbon Pick-up.
At the end of a heat of steel in an arc furnace, it is desirable to keep the arc length to a minimum in order that the refractory wear should be minimised and also to effect the best heat transfer to the metal. However, as the arc length decreases and the electrode approaches the metal surface (even penetrating the slag covering), there is a danger of electrode dipping and a consequent solution of the carbon in the steel. This is a serious matter to the steel maker who may be striving for carbon contents as low as 0·05 per cent. Most modern regulators are impedance-sensitive and there is no difficulty in achieving this important requirement.

(3) Minimum Disturbance on the Distribution Network.
As indicated above, it is impossible to eliminate disturbances and it is impossible to limit the magnitude of these disturbances by means of a regulator. However, a rapid response regulator with a high speed will limit the duration of these disturbances.



A pouring view of one of the three 40 ton arc furnaces installed at Brymbo Steel Works Ltd

At the other extreme, there is a point of view which says that during the melting down period the electrodes should remain substantially fixed, and that the transformer winding should have in series with it a saturable reactor which itself limits any current surges which may be caused by scrap falling against the electrodes. At this stage only development work has been done on this approach, and as far as is known there is no production installation working on this principle.

Circuit Reactance

The desired level of reactance is determined by the electricity supply authorities. The steel maker obviously wants to keep his total circuit reactance to a minimum, but by doing this the short circuit currents are increased. The electricity supply undertaking will therefore require a minimum reactance, which for a large arc furnace will probably be of the order of 40 per cent. This 40 per cent is referred to the top voltage of the furnace transformer, but at lower voltages the reactance will be larger than this value and in fact larger than necessary.

Top charging of one of the 50 ton furnaces at Round Oak Steelworks. The superstructure, comprising refractory roof, electrodes and masts, is swung aside to allow the charging bucket to be placed in position by crane above the open hearth of the furnace

It is a fact that with a large arc furnace, conventionally designed and with reasonable care having been taken to reduce reactance to a minimum, then the reactance will be of the order of 40 per cent. This figure includes the reactance of the transformer which by itself is 10 per cent with the most economical construction.

There is very definitely an argument in favour of having a more expensive transformer with a lower reactance (of the order of 5 per cent or even less) and making special efforts to reduce the reactance of the busbar and flexible cable system. This type of arrangement would bring the total reactance down perhaps to something of the order of 30 per cent, in which case it would be desirable to have an additional reactor which was switchable. This switchable reactor would be in circuit during the melting period when the heavy surges occur but during the refining period on the lower voltages it would be withdrawn from circuit.

Two curves are given in Fig 3 for a 20 MVA 80 ton furnace, one of which shows a fixed reactance system and the other shows a variable reactance system. It can be seen that on the lower voltages there is an improvement of 4 per cent in efficiency. Taken over a year's working, this can show a saving of over 500 000 units of electricity which will cost in Britain of the order of £2 800. The cost of the reactor in this case would be approximately £7 000 and it can be seen that an argument can well be made to justify its cost.

The leads to the centre electrode of an arc furnace are shorter than the leads to the outer electrodes and there is a consequent reduction in the reactance in the centre phase. This reduction in reactance leads to the development of more power in the centre phase. In a conventionally designed arc furnace, this centre phase electrode is nearest to the back structure of the electrode raising and roof slewing mechanism, and in this neighbourhood there is no furnace opening. Opposite this area and on either side there are openings—the side door, the main slagging door and the pouring spout—and these help to dissipate heat from the side walls. There is therefore a greater heat build-up on the side walls nearest the back structure because there is no opening and this build-up is further aggravated by the lower reactance and consequent higher power on this centre phase, which can lead to excessive refractory wear on this section of the side walls. It is a fact that the side walls become due for re-lining largely because of the failure in this area.

It is therefore desirable, particularly on large arc furnaces, to attempt to balance the reactance of each phase in an effort to prevent this hot spot developing on the side wall refractories nearest the back structure. To this end, reactors can be placed in the centre phase bus-

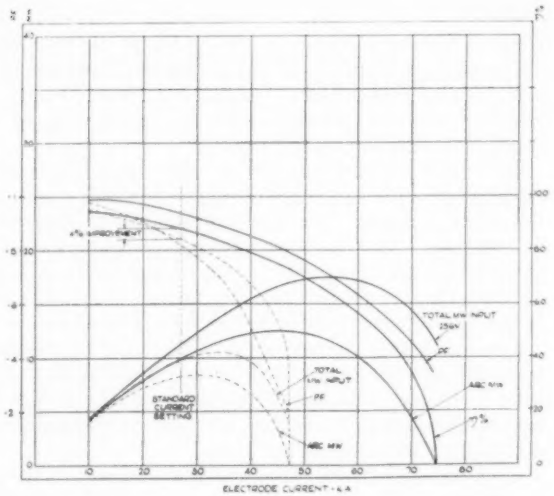


Fig 3. Comparison of characteristic curves of two transformer systems drawn for a refining voltage of 256. The full line curves are for 5 per cent reactance (referred to top voltage of 400) with additional switched reactance withdrawn at 256 V. The broken line curves are for 10 per cent reactance (referred to top voltage of 400)

bars consisting of packets of broken laminations which are placed around the busbars and so form a reactor in which the busbars themselves are the windings.

Mechanical Considerations

Mention has been made of high speed regulators and it is perhaps desirable to define precisely what is meant by a high speed regulator. Such a definition must involve the use of two terms. One is the speed of response, which in turn needs defining; the second is the maximum speed, which does not need defining. There are many rather different definitions of the speed of the response, but the following is logical. The speed of response is the time interval between a maintained error signal being received by the regulator to the time that the electrode is travelling at two-thirds of its maximum speed.

A high speed regulator would have a time of response of 0·1 second and a maximum speed of 30 ft (9·14 m) per second.

It is obviously important that the rigidity of the structure carrying the electrode—the electrode clamp, the horizontal electrode arm and the vertical electrode mast —should be rigid enough to accommodate the rapid accelerations and consequent inertia forces involved in achieving such times of response. If a speed of response of 0·1 second is to be utilised, then the natural periodicity of the electrode arm and its associated structure should be at least five times this, *i.e.* 50 per second. This necessitates very careful design of the electrode supporting structure to give the necessary stiffness.

Furnace Transformer

An arc furnace transformer has to be of special design for rigorous duty. The emphasis will be on mechanical rigidity to enable the windings and the electrical insulation to withstand the heavy mechanical stresses set up by the high current surges.

It is desirable for the larger arc furnace transformers of 7·5 MVA and upwards to be on the 33 kV network. Such a furnace transformer would consist virtually of two transformers mounted in a common tank. The first transformer would be a regulating transformer, perhaps an auto-transformer. All tap changing would be done on this regulating transformer. The second transformer would be a fixed ratio transformer from about 20 kV to the voltage range which corresponds to the tap selected on the regulating transformer.

If power factor correction is desired, then it is preferable to bring out terminals from the regulating transformer so that the voltage on the power factor correction capacitor varies as does the voltage on the secondary of the transformer. In this way, the correction applied to the transformer varies roughly in proportion to the load taken from it.

Power Factor

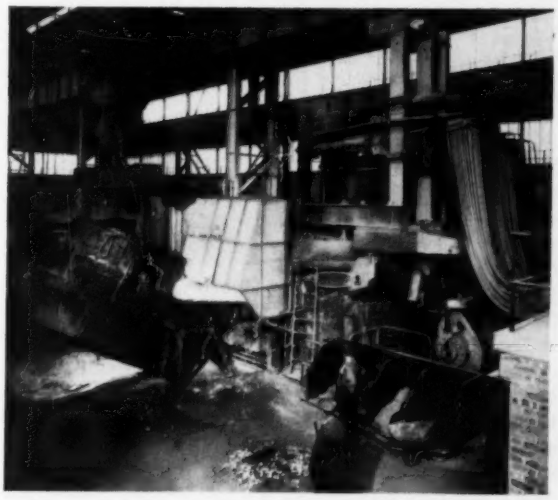
The power factor of a large arc furnace varies considerably in accordance with the typical curves shown in Fig 2. When the furnace is operating correctly, with an average current corresponding to the point X in Fig 2, the average power factor will be of the order of 0·85. This is quite a good industrial power factor and in many instances it has not been found necessary for further correction. However, depending on the particular electricity authority's tariff, it may be necessary to improve this to an average power factor of 0·9.

Tap Change Gear

It has been accepted in this country that 'on-load' tap change equipment on the transformer is necessary for large arc furnaces. Great success has been achieved with resistor-bridging tap change equipment, and resistance tap change equipment is found to require very much less maintenance than reactor bridging gear.

Circuit Breakers

There are two basic types of main circuit breaker available for use with large arc furnace transformers. The first type is the bulk oil circuit breaker which is relatively cheaper but requires maintenance of the oil. The second type is the air blast circuit breaker which is capable of up to 50 000 operations without maintenance of the contacts.



Molten metal from the pre-refining vessel is here being poured from a ladle into a 40 ton furnace by means of a launder projecting through the charging door

The duties of a circuit breaker on a modern large arc furnace installation are not as severe as might be supposed, because much of the work previously imposed on the breaker is taken by the 'on-load' tap changing gear. Other considerations have to be taken into account and the choice of breaker will be influenced by such factors as operating voltage, supply system, transformer design and other equipment on the network.

Electric Resistance Furnaces and their Applications

*R O'Donoghue**

Introduction

THE history of electric resistance furnaces may be said to have begun commercially some 40 years ago. As with most innovations, considerable opposition to their use was experienced and this continued for some years. Gradually, however, the inherent advantages of the equipment in terms of temperature uniformity, reliability, and ease of maintenance broke down the prejudice against them and the use of electric furnaces of all kinds grew more widespread. With the growth of metallurgical knowledge—in which, it may be said, the research of the furnace manufacturers played no small part—heat-treatment has developed from a traditional art to a science. Requirements have become more stringent, but electrically heated furnaces have been able to keep pace with the demands made upon them, and from the small beginnings of less than half a century ago has grown an industry which in 1958 exported equipment worth well over £1¼ million.

Advantages

Precision of control, uniformity of chamber temperature, and clean working conditions are characteristic of electric furnaces. Automatic, recording, and programme controllers are available to ensure the widest measure of regulation, while the fact that there are no deleterious gases of combustion and problems of fuel storage or fuel feeding have brought about what is virtually a revolution in the cleanliness of heat-treatment shops. Heating elements may take a variety of forms, but they can readily be disposed in the furnace chamber to give maximum temperature uniformity; they can be graded also to that end. Moreover, they are normally placed on the internal walls of the chamber where they are free to radiate heat direct, and thus may operate at a temperature well within their capacity. This is conducive to long working life and thus lower maintenance costs. Such positioning, too, enables chamber temperatures to be attained with maximum economy.

There are several other advantageous factors. Generally speaking, for a given output an electric furnace requires less valuable floor space than an equipment heated by other means; the fact that fuel storage is not required has already been mentioned. Installation normally presents fewer problems; the running of the necessary power supply is a comparatively simple matter.

The various points mentioned above could doubtless be expanded, but those with experience of electric furnaces will recognise the factors covered; those without such experience can hardly help admitting that the case for such equipment is indeed a strong one; and it is re-inforced by the increasing number of installations being brought into use in those industries faced with a competition so severe that they must for their very survival weigh most carefully all the aspects of their capital and operating costs.

* Wild-Barfield Electric Furnaces Ltd

Types of Equipment

It is obviously not possible in an article of this length to detail all the many different types of electric furnaces used in industry. Probably the most effective way of showing the value of such equipment is to cover several industries that are extensive users of electric furnaces, showing how their output is obtained and describing some of the plant used.

Furnaces for Light Alloys

There is perhaps no other industry concerned with heat-treatment where the use of electric furnaces is so widespread as that dealing with the manufacture and processing of aluminium and aluminium alloys. It may even be said that much of the growth of the electric resistance furnace can be attributed to the expansion of the aluminium industry. There are two main reasons: cleanliness of the furnace and the fine degree of temperature control available.

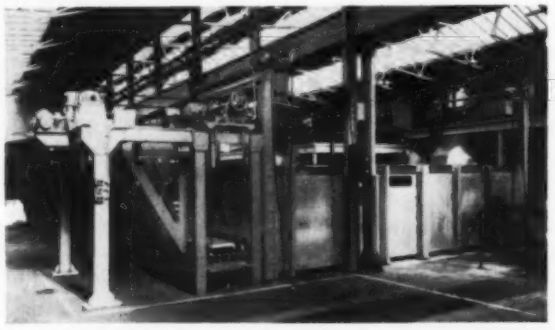


Fig 1. A typical billet heating furnace which will accommodate billets up to 9½ in (24 cm) in diameter and 18 in (46 cm) long

When considering electric resistance heating it should be remembered that in the case of all heat-treatment processes below approximately 700 deg C, heating is indirect, with little radiation effect. Thus in order to impart heat from the furnace elements to the charge, some form of artificial air circulation is necessary, as heat transference by means of natural convection currents is too slow. An efficient air circulation system ensures also that a high degree of thermal uniformity is obtained throughout the furnace charge space. The heating and heat-treatment range of aluminium and its alloys falls below the temperature limit of 700 deg C mentioned above, hence furnaces for processing the metal are necessarily fitted with air circulating fans. These may be

of the simple paddle variety, of the high speed centrifugal type—which greatly reduces heating times—or, in certain special applications, of the double entry type. In the case of low temperature ovens, which are frequently used solely for artificial ageing, the heating elements are usually situated externally in enclosed batteries. With lower temperature furnaces, the fan is attached directly to the extended spindle of the driving motor, while for the higher temperatures in this range the fan shafts have water- or air-cooled bearings and are driven through vee-ropes by an independent electric motor.

Slab and Ingot Heating

Aluminium and aluminium alloy slabs or billets need heating to 525 to 575 deg C or so, depending upon the alloy, to enable them to be passed through either the rolling mill or the extrusion press. Fig 1 illustrates a typical example of a billet heating furnace. It is fitted with six rows of free-running diabolo rollers in the hearth and accommodates billets up to 9½ in (24 cm) in diameter and 18 in long (46 cm). In this particular installation, two billets together are always required at the discharge runways, since they are used in an aluminium cable sheathing press in which each billet extrudes into a semi-circular form, the two semi-circles then being pressed together over the cable. An unusual feature of the furnace lies in the air circulating system, which consists of two double-entry type fans, one at each end, which give longitudinal air circulation. The heating elements are suspended in the upper portion of the furnace chamber in the air circulation ducts and are easily removable for inspection and maintenance.

Annealing

The purpose of annealing aluminium strip or sheet is to soften it after the work-hardening effect of rolling, and to make it suitable for further working or processing. This is largely carried out in batch type equipments in which the coiled strip is loaded and held between 400 and 500 deg C for a predetermined length of time. A typical electric furnace installation for this application is shown in Fig 2. It depicts one of two twin-chamber equipments capable of holding charges weighing up to 12 tons. For lengthy soaking periods, the electrical loading can be reduced to one-third by means of delta-star switching, which in addition to economising on power consumption has the effect of reducing undue wear on control gear.

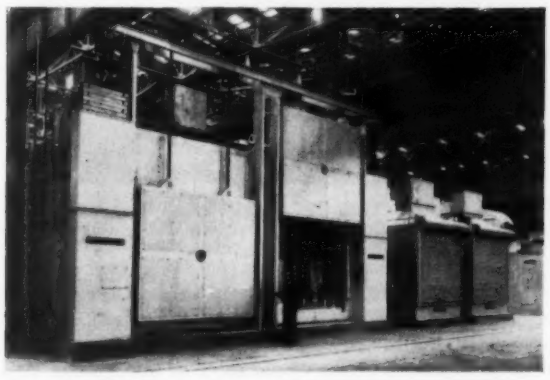


Fig 2. A twin-chamber annealing furnace capable of holding charges up to 12 tons

The production of aluminium alloy articles involving a pressing operation inevitably brings in the question of the grain size of the metal from which the items are made. It is generally admitted that the smaller the grain size the better the deep drawing properties of the material and the more superior the finish on the final product. To obtain this desirable quality in sheets or discs, the ideal annealing cycle to be carried out is that of heating the material to the required temperature in the shortest possible time and to ensure as far as is practicable that the whole piece passes through exactly the same temperature cycle. This individual treatment, which makes the entire surface area available for the reception of heat, becomes an essential condition in the annealing. With this in mind, the continuous 'flash' annealing furnace has been developed. The readiness with which electric resistance heating elements can be disposed in a furnace chamber to give the conditions required, and the ease of control of temperature to within precise limits, provide a good example of the effectiveness of electric furnaces for such critical applications.

Fig 3. Part of an installation of electric furnaces for gas carburising motor vehicle parts

Other processes involved in the heat-treatment of aluminium and light alloys include precipitation hardening and solution heat-treatment. For both these applications electric furnaces are available to give first-class results.

The Motor Vehicle Industry

Developments introduced by the electric furnace industry include means of reducing the time taken for certain processes hitherto of relatively long duration. These increase the output of a piece of plant over a given time. The outstanding example is that of gas carburising, which enables carburising to be effected in a fraction of the time taken by the older pack or box carburising method.

It is hardly surprising, therefore, that motor vehicle manufacturers, successfully fighting competition in overseas markets, should have seized upon such a development as an important means of reducing production costs, and they are—with the many firms closely associated with the motor industry—probably the largest single group of users of the gas carburising process. In addition to the greater rapidity of the treatment, as opposed to older methods, the quality of the work produced in respect of the type of case is much superior. Two methods of gas

carburising are commonly used: in the first, prepared gases are employed as the carburising medium, and in the second, suitable liquid hydrocarbons are fed to the furnaces where they pyrolise to form carburising atmospheres.

This particular application is typical of those in which electric furnaces are playing their part in increasing output and improving the product at one and the same time. Fig 3 illustrates a typical gas carburising installation for treating motor car components.

Other examples of the way in which electric furnaces are helping to reduce costs of production are found in bright annealing furnaces, which eliminate the need for subsequent pickling or cleaning, and bright brazing furnaces which enable quite complicated components to be made up from simple parts brazed with copper or silver solder, and thus cut down machining time and material wastage.

Fig 4. A shaker-hearth furnace for the carbonitriding of relatively small components

A development of relatively recent origin is the process of carbonitriding. This is carried out with an atmosphere similar to that employed in gas carburising but with the addition of a small percentage of ammonia. The effect of the additive is to lower the temperature of treatment and to enable a less severe quench to be used, both of which tend to reduce distortion and so save subsequent grinding time. This process is carried out in electrically heated batch furnaces or in continuous equipments and is displacing salt baths to an increasing extent owing to the elimination of post-treatment removal of salt and the dangers of rusting, and to the improved working conditions. Probably the greater part of carbonitriding—particularly of relatively small components—is carried out in furnaces of the continuous type. In Fig 4 will be seen a shaker-hearth furnace for the carbonitriding of automobile petrol pump parts. As the title of the equipment suggests, work is moved through the heated zone on an oscillating hearth tray, the strength and frequency of the forward motion governing the time taken for components to pass from the loading hopper to the quench tank and thus, for a given temperature, the depth of case to be obtained. The duty of the operator is limited to loading the hopper with work and removing the treated material from the quench tank where it is retained by catch baskets. A greater degree of automatic operation can be achieved by the installation of a belt type quench extractor and by arranging for belt or vibrator feed of components from the previous stage of the production line to the feed hopper or indeed to the hearth tray direct.

Continuous furnaces do not fall into any particular category in the automobile industry, since the charges and processes are so varied. For handling heavier items, for example, the walking beam type of furnace is frequently used. The installation depicted in Fig 5 is one of two similar furnaces in Europe's largest automobile wheel factory. It is used for preheating wheel blanks prior to swaging at a rate of three tons an hour and has a maximum electrical rating of 720 kW; it operates at up to 950 deg C. In the higher temperature ranges, the walking beam type of equipment is usually preferable to mesh belt or slat conveyors.

Among the variety of equipments finding a wide application in the automobile industry is the rotary-hearth type, which has the advantage of occupying a small amount of floor space relative to the output obtainable. In such furnaces labour requirements are reduced to a minimum, since the loading and unloading operations can be carried out by one operator, the charging and discharging doors normally being adjacent. All types of work can be treated and a typical charge would consist of crown wheels, pinions and shafts.

Mention was made earlier of gas carburising and carbonitriding. In some circumstances it is important to have equipment sufficiently versatile in its application, not only to cover those processes, but that of straight hardening as well. Fig 6 illustrates a furnace which falls into that category. A feature of the equipment is that once work has been loaded into the furnace, it does not come into contact with air until its removal either from the built-in quench or cooling station. Thus any difficulties arising from scaling are obviated. This type of furnace is normally referred to as a sealed quench equipment and is becoming more widely used where production conditions require a clean finish and complete control of atmosphere conditions throughout the heat-treatment process.

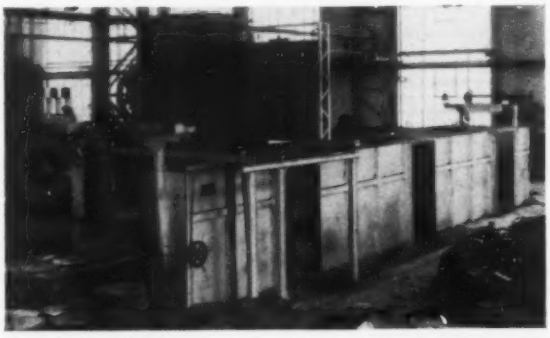


Fig 5. A walking beam type of furnace for preheating wheel blanks. It is installed in the largest automobile wheel factory in Europe

The foregoing examples are only a few of the types of electric furnaces to be encountered in the automobile and associated industries. Car manufacturers have always been to the fore in the application of automation and automatic processes, and electric furnaces materially assist to that end.

General Industry

Toolroom Heat-Treatment. Unless their heat-treatment is carried out properly, any time spent in fashioning tools for industry is virtually wasted. Therefore, when considering furnaces for toolroom use, the questions of precision of temperature control and uniformity of chamber temperature are paramount. Because electrically heated furnaces can provide the precision and uniformity to a greater degree than equipment heated by other means, their use in toolrooms is growing more and more widespread. Additional contributing factors are minimum costs of installation, operation and maintenance, and the comparatively small amount of floor space occupied, many of the equipments being completely self-contained. Simplicity of operation also ensures that in many instances unskilled or semi-skilled labour can be employed upon operations normally only undertaken by skilled personnel of great experience.

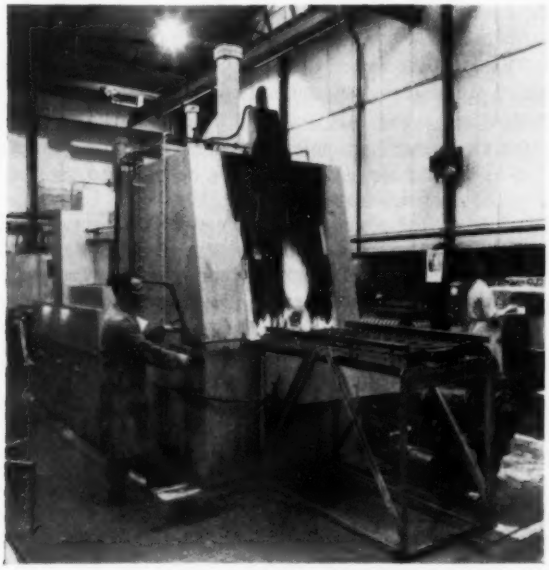


Fig 6. A versatile furnace of the straight-through type for gas carburising, carbonitriding, and hardening

It is difficult to generalise in the matter of the sizes of electric furnaces designed for toolroom applications, for to-day tools can be encountered in such a diversity of sizes from the very large to the very small. Normally, however, where reference is made to toolroom furnaces, comparatively small units are indicated. Fig 7 shows a forced-air-circulation furnace for toolroom tempering and secondary hardening. The workbasket nominal dimensions are 10 in (25 cm) diameter by 10 in (25 cm) deep, which are adequate for most requirements. Another example is a batch type of equipment for hardening and other applications; the door opening measures 9 in (23 cm) by 5 in (13 cm) and the chamber length is 18 in (46 cm). These are furnaces typical of those supplied to toolrooms. It should be borne in mind that although they are comparatively small, their design and construction are such that they may well be used for production heat-treatment where the output is insufficient to warrant the installation of large models.

Furnaces for Technical Education

Not infrequently small electric furnaces are to be found in technical schools and the like, for in addition to being fundamentally safe in operation they reproduce as it were in miniature the conditions to be encountered in heat-treatment shops in industry, and thus students are able to learn the operation and characteristics of equipment similar to that which they will meet in employment. A point appreciated by instructors is that electric furnaces are quiet in operation.

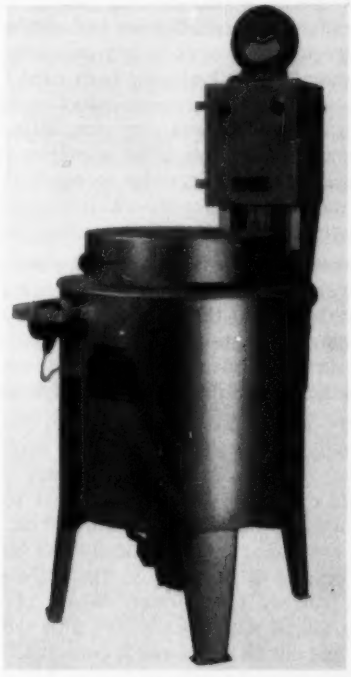


Fig 7. A forced-air-circulation furnace

Summary

In an article of this nature, the difficulty lies not so much in what to include as to what to omit. Electrically heated furnaces are employed so widely and upon such a variety of applications that a great deal must perforce be left out. The industries mentioned, however, are very large exponents of heat-treatment allied to quality production, and it is felt that the ground covered—in addition to the lesser sections concerning toolrooms and technical education—is sufficient to give an indication of the way in which electric furnaces are playing a vital part in ensuring that, as far as heat-treatment is concerned with quality, the products of industry shall not be found wanting.

A Survey of Induction Heating

*K L Moon**

FOR nearly 50 years the use of electric power for the heating of ferrous and non-ferrous metals for a variety of purposes has been steadily developed. Considerable impetus was provided by two world wars, during the first of which the USA was able to make appreciable headway in the art of electrical steel-making, despite the fact that both Germany and Great Britain had carried out considerable development work in previous years. Prior to 1914 induction heating had only been used for melting high quality steels in the coreless induction furnace, but largely because the tool was very new, little or nothing was done to take advantage of the principles and properties of induced currents in order to apply them to the heating of metals for processes which required temperatures lower than those required for melting purposes.

In the period between 1920 and 1939 great strides took place in steel melting by the induction method and in consequence brought in their train the first major developments of induction heating for hot working of metals, the controlled surface hardening of precise shapes, and the joining together of metals at elevated temperatures.

The vastly increased demands for high quality metals and the production of all types of direct products of the ferrous and non-ferrous metals industry resulted in considerable expansion of the scope and technique of induction heating which has been carried on at an ever-increasing rate since 1945. Basically the technique of induction heating is founded on the principles of the alternating current transformer. When two electrical circuits are linked magnetically, the alternating current flowing in one circuit will cause a current to flow in the other, the extent of the induced current being a function of:

(a) the magnitude of the primary current

(b) the ratio of the number of turns in the two circuits

(c) the degree of magnetic interlinkage.

It is a prime function that the voltage induced in the part under consideration is effected without direct electrical connexion to the source of power. The effects produced by the electric current are:

(1) heating; (2) magnetic; (3) chemical.

The induction heating engineer and the user who puts the technique to use are concerned with the heating and magnetic effects and must engineer the harnessing of the two to produce the generation of heat in the quantity required and in the prescribed place, making use of the electrical loss characteristics of the material to be heated.

With a changing alternating current the distribution throughout the conductor is non-uniform; the current tends to flow in the outer surface skin, so that the magnetic linkages and the coupled reactance have minimum values. This 'skin effect' is more pronounced as the frequency increases, and because of this, thin-walled copper tubing is widely used in the manufacture of high frequency inductors and work coils. This 'skin effect' is put to great advantage in the surface hardening of ferrous components, where the depth of penetration and the heat-affected zone have to be precisely controlled in order to give the requisite hardness to a prescribed depth.

There are two major sources of high frequency current which are used for commercial applications of induction heating:

(a) Generator equipment basically of the rotating electrical type, which can be designed to produce frequencies from 500 c/s to 10 000 c/s economically, and which are at present manufactured in sizes ranging from 25 kW up to several thousand kW in size, although in some instances economy dictates that the parallel operation of a number of smaller sets can give considerable advantages in terms of space occupied and flexibility. Present tendencies are towards development of water-cooled vertical motor alternator sets of intermediate rating.

(b) The second class of generating equipment is that provided by the thermionic valve generator which can provide frequencies from 200 000 c/s up to 20 Mc/s and having unit sizes up to and including 160 kW.

Using Mains Frequency Power

We have mentioned the two major forms of medium and high frequency generating equipment, but it must not be assumed that these are the only sources of induction heating power. An ever increasing source of power, and one which is finding increased favour within industry, is that derived directly from the supply mains at a frequency of 50 c/s. Mains frequency power is now being put to increasing use in a variety of ways which would not have been considered economical a decade ago. These include:

(1) heating large sections of ferrous and non-ferrous materials to forging and rolling temperature.

(2) heating small sections to the magnetic change, or curie, point.

(3) heating for the purpose of normalising, stress relieving or annealing.

It can be said that there are uses for all frequencies, and in certain cases single frequencies are used for a complete cycle of heat treatment or heating application. There are

* Industrial Heating Division, Garringtons Ltd

other cases where the use of different frequencies can have considerable value. The major fields in which induction heating in one form or another has proved, and is continuing to prove, increasingly advantageous are dealt with under separate headings.

Heating for Forging

In order to produce materials which can be of use in either the commercial or domestic field it is necessary to heat both ferrous and non-ferrous metals to a high temperature in order to be able to carry out further reducing or forming operations. Induction heating now stands in the forefront of all the methods used for raising the temperature of metals to forging temperatures and the reasons for selecting induction heating for this purpose can be stated as follows:

(1) The great speed of heating as compared with conventional furnace methods gives greatly improved surface finish of the billet. As the calculation of the heating time takes into account the fact that the heat is generated in the outer surface of the material and is conducted to the centre, it follows that the shorter the heating time the greater the temperature differential which appears between the outside and the centre of the piece, and it is therefore necessary to choose a heating time which will allow an acceptable temperature differential to be achieved. These heating times are reckoned in minutes as compared with hours for the conventional types of furnace. It follows therefore that the extremely short period of time for which the billet is at temperature results in a vastly reduced amount of scaling and consequently a considerable saving in steel per annum.

(2) Greatly improved surface finish results from the absence of contaminants which are commonly to be found in the conventional gas- and oil-fired furnace.

(3) In a correctly designed induction heating furnace, the power which is applied to the material and the time for which the material is subjected to this power are closely controlled, and it follows therefore that the degree of uniformity between billet and billet is of an extremely high order.

(4) As a result of the considerable saving due to reduced oxidation and scaling, and the great uniformities between billet and billet, it is possible to reduce by up to 3 per cent the billet weight which is necessary to fill the forging die, resulting in very much closer flash control.

(5) As a result of the greater concentration of power at the right place, the equipment can be designed to take up a very much reduced area, and because of the absence of radiated heat, the working conditions are vastly improved. There are relatively no fumes from induction heating furnaces.

(6) Whereas conventional furnaces require a considerable period to achieve their operating temperature, and in consequence involve additional labour expenditure, the induction heater does not suffer from such a disadvantage. The time taken to start up an induction furnace is the transit time of one billet through the complete coil system and can be of the order of four minutes for a 1 ton/hour furnace. During periods of press stoppage or die change the induction heater can be shut down and started up at the appropriate time when forging operations recommence. Thus the heavy scaling which would take place in the conventional furnace is reduced to the very minimum in the induction furnace. At the end of the shift, the induction heating furnace can be closed down, leaving the contents—usually 15 to 20 billets—to go cold and to be ejected during the starting transit when work commences at the beginning of the next shift, whereas in the conventional furnace charges amounting in some cases to tons of stock have to be allowed to go cold with resultant severe oxidation. Alternatively the furnace can, with special arrangements, be emptied under power to leave practically no billets unforged.

(7) It has been proved that increased productivity results from the very close mechanical control of the work-piece and the provision of rhythmical working conditions. These factors, together with close control of power into the piece and time for progressing the piece through the induction heater, and the precise electrical adjustment which is available, mean that the operation of the forging unit can be at optimum efficiency at all times.

(8) The precise temperature control and the absence of scale due to the speed of heating result in increased life of the forging die and reduced die costs.

Wide Range of Frequencies Available

Induction furnaces are designed upon several systems in order to achieve the greatest economical advantage from the size of stock being heated and the range of frequencies available. Consideration of the range of stock size to be heated can be used to indicate which frequency is most likely to be suited to the product. For round bars of sections less than $\frac{3}{4}$ in (19 mm) diameter or section, a frequency of 8 000 to 10 000 c/s is justifiable. For stock sizes $2\frac{1}{4}$ in (57 mm) square or round and above, frequencies in the order of 1 000 c/s can easily be utilised.

A general view of a forging press unit comprising a 4 000 lb (1 814 kg) induction heater, a 2 000 ton forging press and a stripping press. The heater is a dual frequency unit with a rating of 700 kW and can handle a stock size from $1\frac{1}{2}$ in (38 mm) square to 4 in (102 mm) square

Additionally, advantage can be taken of the change of penetration depth at curie point, and this means that a frequency of 50 c/s can be used in this way to heat sections down to 2¼ in (57 mm) square or round to the curie point prior to using a higher frequency to take the stock to forging temperature. For ferrous materials of 8 in (20 cm) diameter or cross section and over, mains frequency at 50 c/s can be employed to raise the temperature through the whole range to forging temperature. Thus we see that there is at the disposal of the forging engineer a comprehensive range of frequencies which can be employed to heat stock ranging from ¾ in (9.5 mm) in diameter to the largest sections manufactured, and the selection of the correct frequencies depends upon the limitations imposed on the furnace concerned by the range of stock to be heated.

In general it can be said, therefore, that for stock sizes up to and including 2¼ in (57 mm) square or round a single frequency furnace can be usefully employed at an economic efficiency. From 2¼ in square or round up to 8 in (20 cm) square or round, a mixture of mains frequency and a medium frequency can be of considerable advantage in that, by making use of the change of penetration depth at curie point, a higher coil efficiency can be produced with lower capital cost. For sections in excess of 8 in round or square, equipment using mains frequency at 50 c/s can be employed throughout with consequent economic advantage in terms of plant capital cost. In most forging processes, the range of stock sizes to be treated varies within a wide range and in consequence, having made a first choice of the frequency at which the stock is to be treated, it follows that a range of coils will be necessary in order to cater for the wide variations in stock size. At this point it is necessary to effect a balance between efficiency from an electrical power consumption point of view and economy from a capital plant view point. It is generally considered that, from an efficiency point of view, a change of coil is necessary for every 25 per cent increase in section.

Design of Inductor Coils

In the case of the single frequency furnace, the high frequency induction coil can be wound to either a round or square section and is designed to give clearance between work piece and inductor coil consistent with mechanical operation and thermal and electrical insulation. The inductor coil itself is made from high conductivity copper of hollow rectangular section. This section takes advantage of the penetration depth at high frequencies and provides a means of cooling the inductor coil by passing water through the tube. A conventional induction heating coil has multiple water cooling circuits in order to take away the heat resulting from the resistive losses in the inductor itself and the radiated heat from the hot stock within the coil. The inside of the inductor is normally coated with high temperature refractory material in order to cut down thermal losses and protect the inductor coil from the effects of radiation. The coils themselves are mounted within a sindanyo box structure, with external electrical connexions at pre-chosen positions in the interests of coil interchangeability, and the whole assembly embedded within the box structure with a refractory cement.

In a forge furnace the charge of billets being passed through an induction coil has to be guided during its passage, and conflicting requirements have to be catered for. The first and most important requirement is that the lining of the coil should be sufficiently robust to withstand the wear and tear. For this purpose water cooled skid bars can be inserted into the lining. The second consideration is thermal efficiency, any loss to the skid bars acting directly against this consideration. For small low-powered

A view from the discharge end of an automatic track link hardening machine showing (right to left) loading magazine, 50 c/s preheating zone, hardening and quenching zone, 50 c/s stress relieving zone

furnaces high quality refractory linings are perfectly practicable, but for large robust furnaces skid bars are still the normal fitting.

Dependent upon the type of production for which the machine is designed, various methods of handling can be employed. Where the stock size is consistent and the quantities large, automatic systems are employed making use of magazine loading and feeding into continuous pusher type furnaces. The operation of this type of furnace depends upon a constantly filled magazine, as a failure to load brings in its train a failure to push, and in the interests of safety interlocks must be provided in order to shut down the furnace rather than permit any piece of hot stock to remain in the furnace for periods exceeding those laid down. When the duty is of a more intermittent character, the conveyor type furnaces which can be manually fed and have a lesser degree of mechanisation can be usefully employed, and as the heating time is only dependent upon the conveyor speed, any gap or failure to feed a billet as a result of a failure to load does not affect their passage through the furnace. The induction heating furnace in its more ambitious form lends itself ideally to automation to a very high degree, and there are many examples in existence at the present time where automatic induction heating furnaces discharging by mechanical means feed forging presses which are able to operate at consistently higher speeds than had previously been thought possible. A saving in labour is one of the many advantages which result from such automatic schemes.

Special machines have been designed for making use of the best features of induction heating in order to feed upsetter machines, and while in the majority of cases only part of the work piece is heated, the stock can still be fed automatically from a magazine into one or more coils of appropriate length connected in parallel to the high frequency supply and designed so that the insertion of the following piece, under the control of the pre-determined time cycle, ejects the hot stock already within the coil.

Mechanical problems exist when heating billets of large dimension and considerable weight. In cases such as this it is obviously undesirable to push such billets horizontally along skid rails, and it follows therefore that a unit based on handling individual billets singly is desirable, and that these should be treated in the vertical position. This manner of treatment is practical for billets of the order of 122 to 150 lb (55 to 68 kg) in weight, but where larger ingots are concerned it is desirable to mount the ingot itself on a suitable plinth and design the induction heating coil so that it can be readily lowered in position over the ingot.

Heating for Extrusion

The design of induction heating equipment for non-ferrous materials such as aluminium, brass, copper and cupro-nickel follows similar practice to that for the ferrous materials except that the temperature range is not so high, and in addition none of the materials are themselves magnetic, although all are conductors. The temperature range varies from 500 deg C to a figure in the order of 1 000 deg C and the problems of determining accurately the billet temperature are not in the same order of difficulty as for steel, but still possess problems, as for instance contamination.

Extrusion press operation is of a somewhat different character to that of the forging press and consequently the induction billet heater needs to be capable of dealing with a somewhat different set of circumstances. Rhythmical operation of the extrusion press, although desirable, is somewhat difficult to achieve, and consequently the induction heater has to be able to make allowance for small delays in production which result from the necessity to hold a billet at temperature while at the same time maintaining temperature uniformity within the billet.

Materials having poor thermal conductivity are, by their nature, difficult to handle successfully when the production cycle is variable, and consequently the design of induction heating equipment to make allowance for this condition is based on the principle of one coil, one billet, although a number of single coils can be arranged within the same heating equipment. Contact type thermocouples are used at the lower end of the temperature range, especially for aluminium, aluminium alloy and brass materials, but as the extrusion temperature increases, it becomes more difficult to use contact type thermocouples because of the increase in the degree of surface contamination. At this end of the range temperature measuring devices which make use of the radiated energy of the material can be employed, although there are drawbacks to this due to the masking effect of oxidation at elevated temperatures and changes of surface emissivity. Considerable work is being devoted to experiments designed to produce a thermocouple having good resistance to contamination.

Heat Treatment

The application of induction heating for heat treatment has been widely developed, and characteristically has received its greatest encouragement in the mass production industries where runs of similar components lend themselves easily to this form of treatment. The principles under which this form of heat treatment operates are in general identical with those used for through heating and the variations which determine the form of heating are those of controlled time, power, and method of application. Power at supply frequencies, motor generator frequencies and thermionic valve generator set frequencies are all equally useful in this form of treatment, where once again the component determines the frequency which is ultimately adopted for the final heat treatment. The steels chosen for this form of treatment are in general plain carbon steels, although alloy steels are very often employed because of their special properties. Suitable steels are recorded in the 1955 edition of BS 970 and include EN8, EN9, EN10, EN11, EN12, EN15, EN16, EN18 and EN19. It cannot be emphasised too often that the previous heat treatment specification of the steel is of vital importance; unless the grain size is small, the very short heating times will not permit adequate diffusion, resulting in a complex structure having low hardness values.

The depth of hardness required dictates the frequency which is ultimately chosen to perform the duty, and the weight of material raised to hardening temperature decides the rating of the generator source. The surface hardening of regular components such as shafts, pins, cam shafts, bushes, axle shafts and crank shafts, etc., is effected at frequencies of the order of 400 000 c/s, although an increasing number of such components are now hardened successfully at between 8 000 and 10 000 c/s. Large crank shafts, axle shafts and large tractor gears, mill rolls and heavy crank shafts for diesel vehicles can be successfully hardened at frequencies as low as 3 000, or even 1 000 c/s.

A 50 c/s supply can be used as a service in preheating components to curie point prior to their transfer into a higher frequency zone for final treatment.

Methods of Treatment and Handling

Having decided by examination the frequency which it is desirable to use in order to give the required depth of hardness for the particular component, it is now necessary to consider the method by which the induction heating can be carried out.

There are several methods available, the three most commonly considered being:

(1) the ' single shot ' method of treatment by which the whole of the surface to be hardened is treated simultaneously, being raised to the required hardening temperature and at that point quenched.

(2) a sectional treatment of the surface by which portions are hardened successively, as in the hardening of large gear wheels.

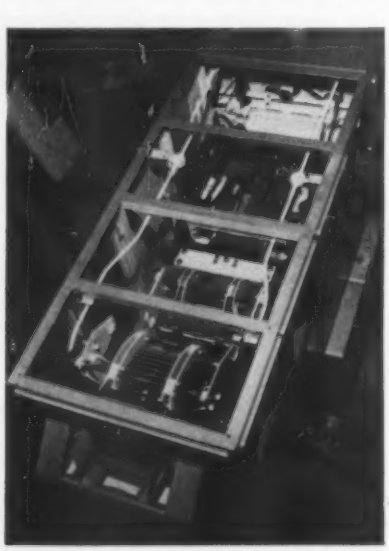
(3) continuous hardening which employs the passage

of the piece at a constant speed through the field of an inductor which heats a relatively small portion of the work at any one time.

A second consideration which has application to all the previously mentioned three methods of treatment is the method of handling the component, and this is dictated largely by the quantity runs available. The automobile industry and similar allied industries have, by the very nature of their products, quantities of similar components available for heat treatment, and in consequence lend themselves easily to automated processes. Regular shaped components lend themselves to simple forms of automatic handling equipment, so enabling the piece to be fed mechanically into the inductor, heated, quenched and discharged without being touched by hand. The larger irregular shaped components, such as tractor track links, can be hand loaded on to a mechanical feed conveyor and progressed by mechanical means into the hardening, quenching and stress relieving positions where they are mechanically ejected or alternatively can be manually unloaded. Larger components such as tractor gears are manually handled on to the loading position and at the completion of the heat treatment cycle manually unloaded. Very often the mechanical handling problems involved are considerably greater than the problems of directly heating the component by induction methods.

Coils for Induction Hardening

Inductors used for induction hardening are generally of the single turn type fed by means of a step down transformer from the high frequency or medium frequency supply. The ' single turn inductor ' can cover an exceedingly wide range, from the simplest tubular copper inductor wound to suit the contour of pins which are single shot treated and dump quenched, to the complicated type of inductor associated with the progressive hardening of axle shafts wherein the inductor coil carrying its integral water passage and associated within the same body with a quench manifold, is designed and manufactured with extreme care in order to project a continuous stream of quenching medium on to the shaft as it progresses through the inductor coil.



A view (with the covers removed) of a special purpose push-rod hardening machine which is designed for hardening a variety of different lengths of push-rod on an automatic cycle. The rating of the power supply is 35 kW at a frequency of 200 kc/s and the machine will operate at a rate of 3 000 push-rods a minute

In the case of surface hardening applications of large mill rolls, multi-turn coils are often employed in order to permit the necessary power to be applied to the surface of the roll. In cases such as this, however, the quench manifold becomes a separate piece of equipment mounted in such a position that the water quench is controlled to the precise point on the body of the roll to ensure adequate quenching out to achieve the desired hardness.

For the continuous progressive hardening of shafts, pins, etc., mechanical devices are commonly employed in order to ensure that the piece being treated does not harden eccentrically. Rotation of the work piece ensures that eccentricity between the inductor and the work piece is eliminated.

Advantages of Induction Hardening

The chief advantages which can be claimed for induction hardening are:

(1) General cleanliness.

(2) Absence of scale in comparison with other methods, due to the speed of heating.

(3) Distortion is minimised.

(4) It lends itself easily to the machine tool approach and can therefore be built into flow production lines.

Induction hardening is not confined only to the carbon steels, but can also find outlets in other specific applications where, because of the speed of heating, or the irregularity of the component, induction heating can be allied to some other process. An example of this is the induction heating of previously carburised components, where, because of the complication of size, together with the shape of the 'as designed' component, it would be very difficult to avoid considerable heated depth. The components are carburised in the conventional manner, and the subsequent induction heating process can be so arranged that the minimum power can be applied in order to achieve hardness in the carburised zone without the necessity of controlling the depth of heating.

A further application of induction heating is in the softening of components which have been previously carburised and conventionally hardened over a large surface and which subsequently require a small portion of that surface to be softened in order that a further machining operation can be carried out. Because of the ease of localisation in the application of induction heating this type of softening operation can be easily performed.

Large Section Heating

Increasing interest has been shown in the use of induction heating for large sections in the order of 16 in (41 cm) square or round and larger. Because of the inherent speed of heating, allied to the considerable saving in space over conventional methods, induction heating is now being considered for heating billets,

blooms and ingots which would previously have been heated in soaking pits or large electric, gas or oil fired furnaces.

At the present time the supply frequency at 50 c/s can be used with advantage, although a much lower frequency could be employed with even greater advantage. For certain very large ingots frequencies of the order of 1 or 2 c/s would be ideal, but at the present stage of development there appears to be considerable difficulty in overcoming the inherent disadvantage of providing sufficiently large capacitance to correct the inductance at such low frequencies. Considerable thought and development is being applied to this problem at the present time and it is hoped that a satisfactory solution will be found in the very near future.

A further field which is receiving considerable investigation at the present time is that of utilising the best features of induction heating with the known advantage of other forms of heating for large section materials.

Two major problems arise in conventional large section furnaces, firstly hearth and roof life in the high temperature zone, and secondly scaling and contamination due to the long times required in the high temperature zone.

The use of an induction furnace for the 900 to 1 250 deg C zone of a heat can offer a solution to both these problems, while the total capital cost will be far lower than that of a pure induction installation.

It is thought that the combination of two forms of heating could result in economies both in capital cost and space required when allied to the other advantages of the induction heating process, *i.e.* speed of heating, absence of scaling, and the reduction in the size of the initial installation.

The Future Outlook

The use, application and development of induction heating processes, which have been progressing rapidly during the last 25 or 30 years, have by no means exhausted the range of applications. It would appear, therefore, that as the development of nuclear power becomes of increasing significance with the installation and commissioning of increasing numbers of nuclear power stations, electric power will tend to become cheaper while the more conventional forms of heating such as gas and oil must inevitably become dearer due to the increasing freight charges and the decreasing quantities of coal which will be available in years to come.

It would appear, therefore, that within the next 10 or 20 years considerable inroads will be made into spheres of activity which, up to the present time, have been the prerogative of the conventional furnace manufacturer. In addition, the human factors which apply are of considerable significance; labour is becoming increasingly conscious of the desirability of better working conditions and this must lead to processes which give a greater degree of cleanliness and a decreasing amount of physical labour. Atmospheric pollution and contamination will ultimately dictate the form which heating will take, and in this regard induction heating is by its very nature the least likely to cause offence.

It will be seen, therefore, that in the field of hot working, surface hardening and treatment, considerable strides forward are being maintained, and throughout the world an increasing amount of installed capacity used solely for induction heating purposes is being commissioned year by year.

A Precision Tool for Industry

Induction heating has passed out of the realm of the laboratory and experimental trial into the sphere of an accepted method of production, a tool of industry which can be applied with precision. In the future, also, with the increase in the demand for high temperature materials, the higher quality heat resisting steels, etc., the application of the induction heating furnace must take its place in the forefront due to the known advantages of the method. Speed, controllability, precision of application, space saving, absence of contamination are all major factors in the fields that lie ahead.

Radio Frequency Heating in the Plastics Industry

Christopher E Tibbs, MIEE *

RADIO frequency preheating ovens have been used in thermo-setting plastic moulding shops for the last fifteen years. The initial introduction of these equipments raised productivity, particularly on the thicker section mouldings, by up to three times. Recent advances in preheating equipment have now made possible another advance at least as big as that initially obtained. This new technique is known as rapid cycle moulding and can under favourable conditions give increases in productivity up to ten times greater than those which are possible without electronic preheating.

A moulding shop using radio frequency preheaters supplied two or three years ago may well be employing three operators, three presses and three old style preheaters to achieve the same production as that which is possible with one operator, one press and one modern preheater. When such great differences in productivity are possible it is extremely important to have a clear understanding of the theory behind what must surely be the most important advance of the last decade in this particular field.

The four curves illustrated are all inter-related. If they are studied correctly, they make possible an extremely good assessment of the cure times which will be achieved with any given set of operating conditions. The first of these four curves shows that the faster the press closes, the higher can be the preheating temperature. The second shows that the higher the preheating temperature, the shorter is the cure time. The third curve shows that the higher the temperature to which the moulding material is preheated, the faster must be the preheating to avoid precuring. The last curve shows that if the cure can be greatly reduced in time, the mould temperature can be substantially increased, thus making a very material contribution to the shortness of the cure time shown in the second curve.

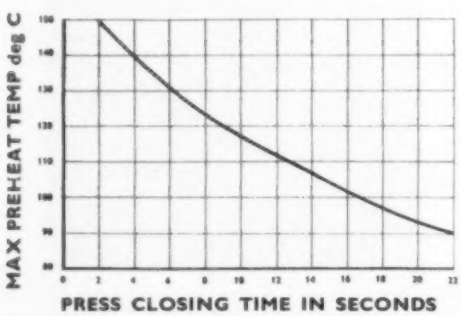
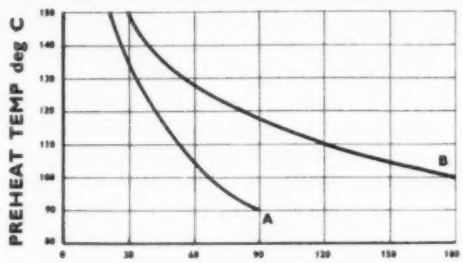


Fig 1

*Joint Managing Director, Radio Heaters Ltd

The factor which dominates the whole of the productivity in the moulding shop is the press closing speed. The term 'press closing speed' must include everything between the instant at which the rf heater cuts off and the application of full pressure on the mould. Reference to



A = $\frac{3}{16}$ in (4·8 mm) thick moulding;
B = $\frac{1}{2}$ in (12·7 mm) thick moulding

Fig 2

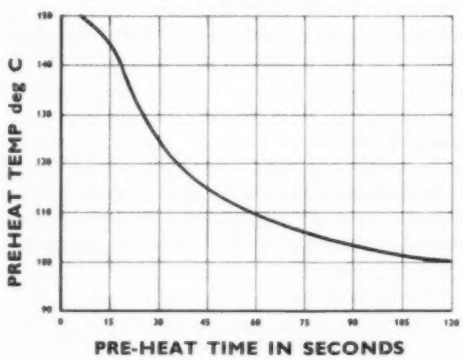


Fig 3

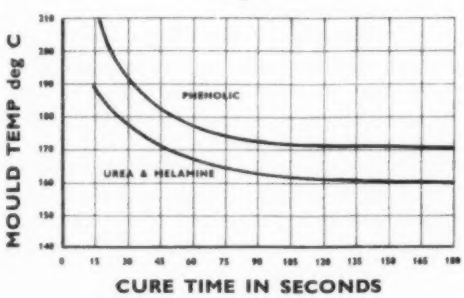


Fig 4

the fourth curve shows that if the press closing time can be shortened to 2 seconds, most plastic materials can be preheated to 150 deg C. If the press closing time is around 8 seconds, the maximum safe preheating temperature will be in the region of 125 deg C. If however the press is very

bad indeed and takes perhaps 16 seconds to close, the maximum preheating temperature that can be safely used will probably not be much over 100 deg C. These figures are purely general indications and must obviously show very great variations from one moulding material to another.

Aids to Rapid Operation

Having appreciated that the ultimate productivity depends entirely upon the shortness of time between the end of the heating cycle and full pressure being applied, all the operations in this time interval want very special study. The more important of these are as follows:

1. The first point to watch is that the operator never allows the plastic material to stand in the preheater after the end of the preheating cycle. All rapid cycle preheaters are therefore arranged so that the lid can be closed without the radio frequency power coming on. Things are arranged so that the operator merely needs to touch a button on the press to start the preheating cycle. Alternatively the cycle can be started by the automatic timer in a semi-automatic press. Either of these arrangements ensures that as far as possible the powder is not ready before the operator is able to transfer it directly to the mould.
2. The next factor which enters into the vital time period which determines the productivity of the moulding shop is the opening of the preheater lid. An oven lid which opens automatically and rapidly at the end of the heating cycle is therefore essential.
3. The actual removal of the moulding material from the preheater and the placing of this material in the press also has to be done within the vital time period concerned. This means that the accessibility and ease of access to the load in the preheater oven is of great importance, as is also the positioning of the preheater. It is essential that the operator transfers the moulding material from the oven to the mould as smoothly and easily as possible.
4. Finally we come to the press itself, and this is usually the dominant factor in the vital cycle of events. In the United Kingdom and a number of other European countries, this part of the cycle is unfortunately very considerably slowed up by the time taken in the closing up of mechanical press guards. It has been estimated that these mechanical press guards alone reduce the maximum achievable United Kingdom moulding productivity to two-thirds of what would otherwise have been possible.

Turning now to the press itself, it is of course absolutely vital that the press closes as fast as possible and that having closed, the pressure build-up is also as fast as possible. A fast closing press with a subsequent slow pressure build-up is completely unsatisfactory. From the first curve it is quite clear that the longest press time which should be regarded as satisfactory is 2 to 3 seconds. Productivity could definitely be increased if the time was shortened below this on moulds where the materials can be handled really fast.

Reducing the Cure Time

The second curve in the group of four shows that as the preheating temperature is increased the cure time falls rapidly. This is particularly the case with thicker mouldings. On $\frac{1}{2}$ in (12·7 mm) thick mouldings, the cure time can be shortened five times if the preheating temperature is increased from 100 deg C to 150 deg C. Bearing in mind the first curve which has already been discussed, this is equivalent to saying that reducing the press closure time from 16 seconds to 2 seconds make it possible to increase productivity five times, provided of course all other factors are looked at simultaneously.

The second curve linking the cure time to the preheating temperature includes the increase in productivity obtainable by raising the mould temperature simultaneously.

Increased Mould Temperatures

The last curve shows that as the cure time is shortened it is possible to increase very considerably the mould temperature without producing surface blistering. Increasing the mould temperature of course makes a very substantial contribution to the reduction in cure time, because the higher temperature preheating has shortened the cure time so much that higher mould temperatures can be used without surface scorching of the moulding. When working with mould temperatures above some 400 deg F (204 deg C) it may be necessary to change from one moulding material to another in order to avoid mould staining. This generally arises from the fact that some powder manufacturers are still not making their materials in a suitable form for moulding with mould temperatures as high as 400 deg F (204 deg C). It is therefore necessary for the user to select a material for this method of operation from among those available.

Fig 5. This 70/80 Mc/s 12 kW preheater will raise a 12 oz (340 g) load of material from room temperature to 150 deg C in 15 seconds. Under the conditions described in the text it can result in a three to one improvement in productivity over older type preheaters

The third curve shows that it is essential, when preheating to high temperatures, to carry out the preheating in a very short time cycle. If the moulding material is being preheated to 150 deg C, the pre-heating time should not exceed some 7 to 10 seconds at the most. A preheating time of 20 seconds can however be permitted if the preheating temperature is in the region of 135 to 140 deg C.

In order to obtain these very rapid preheating cycles powerful plastic preheaters are essential. Not only is additional power necessary to reach the higher preheating temperature, but considerable additional power is necessary to reach this temperature in perhaps one half or one third of the time previously employed. As an example, if a 1 kW preheater was previously used to heat material to a temperature of 100 deg C in two minutes, nine times the power is necessary to heat the same load of material to 140 deg C in 20 seconds. This power requirement may be appreciably raised if quantities of moisture have to be evaporated at the higher temperature, whereas previously the preheating temperature was not high enough to evaporate the moisture. A little thought shows that if the rapid cycle moulding technique is to be fully employed, preheater powers some five to ten times higher than those previously used are required. In order to permit very high preheating powers to be applied without flashover down the pellet, the frequency of the new Radyne H.120 12 kW output plastic preheater is 70 to 80 Mc/s.

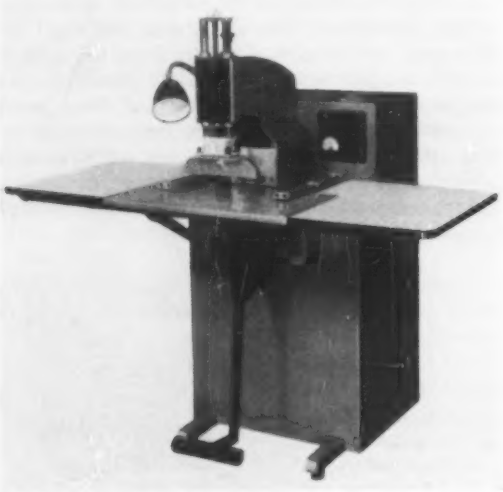


Fig 6. This small rf dielectric welder operates at frequencies higher than 70 Mc/s and is available with power outputs of 800 W and 1·25 kW. This high frequency permits it to weld many thermoplastic materials which could not be welded even twelve months ago

Dielectric Welding of Thermoplastic Materials

In general it is impracticable to make a sound joint of hot bar sealing of PVC and a number of other thermoplastic sheet materials. The only practicable method of using conventional heating for joining these materials is to use a heated knife blade over which the materials to be joined are drawn and immediately thereafter pressed together. While this technique is extremely helpful on some operations, the number of these operations is so restricted that the technique is not widely used.

If however a radio frequency voltage is applied between unheated bars it is possible for the dielectric heating to melt the two plastic sheets while they are being pressed together. However, as the surface layers are in contact with cool tools, the surface of the materials never actually melts, with the result that a perfect weld of excellent appearance can be obtained. During the last ten years an extensive range of highly specialised thermoplastic welding machines has been developed in the United Kingdom.

If plastic rainwear is stitched, it both leaks and tears along the perforations. Dielectric welds are both waterproof and strong. The majority of plastic rainwear in the United Kingdom is now welded on radio frequency welders.

The radio frequency welder shown in Fig 6 is a typical small welder used in the garment trade for the small operations which have to be undertaken. Interesting features of the 1 kW welder are its high operating frequency, which makes flashovers leading to reject garments impossible. After the material has been laid out the tool is brought down by pressure on the foot pedal which simultaneously switches on the dielectric heat between the tools. An interesting feature of this particular welder is that the foot pedal can be turned through 90° so that the operator can either sit in front of the machine or to one side. A large variety of interchangeable lower electrode arrangements is also possible to meet the specialised requirements of the garment trade.

Dielectric welders can be fitted with large cast lower platens mounted directly on to the press frame. On this type of equipment only the top electrode has any rf voltage on it. Using the flat lower plate, one welding electrode is sufficient for each new weld shape. Equipment of this type produces numerous different imitation leather articles including billfolds, wallets, writing cases and book covers. Much of this work is now done on shuttle type jigging in which two operators work on one machine: one loading the material and pushing it in the press, and the other removing it on the far side.

As an alternative to the shuttle arrangement a large rotating table can be fitted on the front of the equipment. This permits more than two operators to be used if desired. Fig 7 shows an 8 kW equipment of this type. The plastic welder fitted to this rotating table is of particular interest as its interference is suppressed, so that it can be used without the need for screened rooms in the majority of countries where there are interference laws. In countries such as the USA all plastic welders have to be used within screened rooms. Such screened rooms are completely unnecessary with British welders of the type shown in Fig 7.

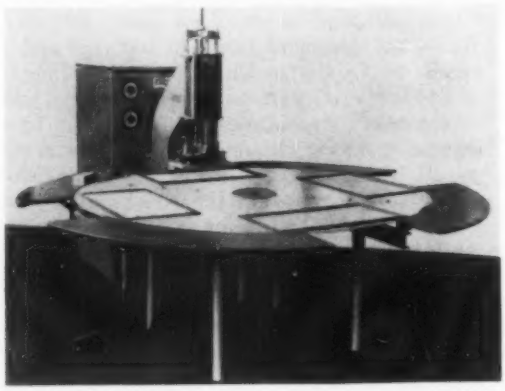


Fig 7. This British 8 kW welder is the first equipment which can be used in North America without the need for screened rooms. This introduction marks a major technical advance

Tools for making profile welds can also have a knife edge to cut through the plastic immediately alongside the weld line. This 'cut welding' method is widely used on many plastic articles including inflatable toys, balls, rings, air beds and cushions. The same technique is also extensively used for such items as the covering of belt buckles and other items where the welded product would otherwise have to be cut out after the welding was complete. The 'cut welding' method makes it possible to weld and then merely press the finished welded article away from the unwanted sheet of material.

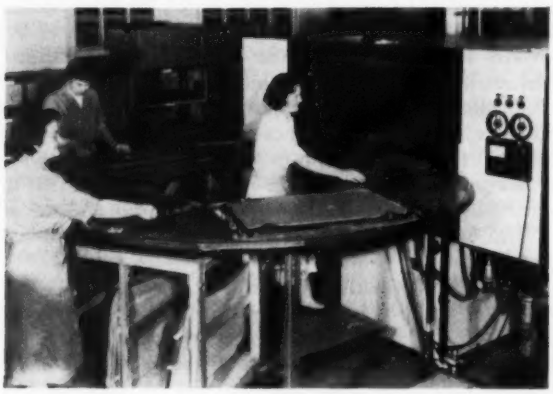


Fig 8. This big press is specially designed for the automobile industry. It will weld the largest American automobile seat cover in a single operation. It operates at a higher frequency than any comparable press available in any other country. This means that rejects due to flash-over are extraordinary low

Applications in Automobile and Furniture Industries

Suitable thermoplastic sheet material placed between two pieces of textile can be used to weld them together. The radio-frequency heating melts the plastic which envelops the textile fibres, thus bonding them together firmly and rapidly. Extensions of this technique make it possible to weld leathercloth and wadding or suitable foamed plastic to prepared hessian, hardboard or even steel sheet. It is possible to bond together almost any material by the dielectric method. This process has an extremely wide application, particularly in the automobile trim and finishing trades. The big plastic welding press shown in Fig 8 can weld the largest automobile seats in one operation. This same technique is also likely to transform the manufacturing methods in the furniture industry, as it makes possible the production of upholstery of all types without the need to employ sewing machines.

Furniture is already on the market in the United Kingdom on which textile materials are dielectrically welded through suitable wadding to prepared moulded plywood bases.

Dielectric welding makes possible large unbroken waterproof areas of backed and unbacked plastic sheeting. This technique is used not only for children's paddling pools but also for full-size swimming pools, static water tanks, building site covers, tarpaulins and cinema screens. Special plastic welding equipments are designed to run on rails in order to deal with the welding of straight seams over very large plastic areas. If reinforced plastic material is employed, these big area waterproof plastic projects will last even in the open air for a considerable number of years and are extremely durable even in the most adverse conditions.

The uses of dielectric welding in the packaging field extend from liquid shampoo packs to the plastic liners fitted inside cardboard cartons which are used in carrying corrosive liquids. In other directions the uses extend from the tropical sealing of spare parts to the waterproof packaging of lifeboat provisions. If medical dressings are sealed within thin nylon film they can be sterilised in an autoclave after sealing and will remain sterile for very long periods.

Specialised Packing Techniques

In the medical field radio-frequency welders are being used to package arteries and other human body spare parts in water-clear PVC before storage in a deep freeze cabinet. This technique permits the surgeon to examine his stocks of human spare parts to see if those available will fit the patient in the operating theatre. Previously this was not possible without opening up the parts. The same technique permits pathological specimens to be packaged in transparent containers with a few cubic centimetres of formalin. This advance makes it possible for students to handle and examine specimens without causing deterioration.

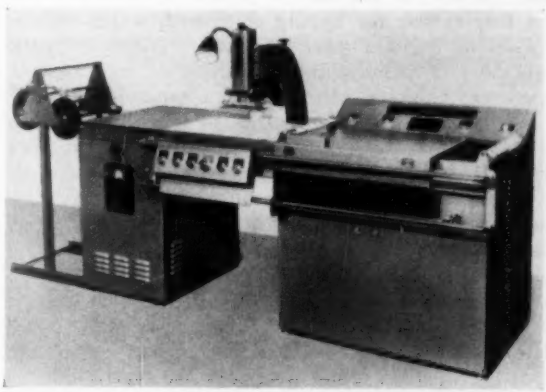


Fig 9. Automation of rf plastic sheet welding is now starting in the United Kingdom. This machine will automatically weld articles from continuous rolls of material, thus materially reducing the number of operators required for plastic sheet welding operations

Automatic Welding Machinery

Automated plastic welding equipment has recently been introduced into the United Kingdom. This highly automatic machinery not only produces a greater number of articles from each machine but makes it possible for one operator to look after several machines. This type of automatic welding machine is likely to extend considerably the uses to which plastic welding is put during the next few years. Fig 9 shows a typical machine of this type.

Radio Frequency Heating in Wood Gluing

J Pound, MIRE, AIEE*

Introduction

The application of rf heating techniques to many of the processes involved in wood fabrication has brought considerable advantages to this specialised industry, principally in the directions of greatly increased speed of production, higher output from the same floor area, more economical use of materials, and in many instances a reduction in the amount of labour required—all leading to a notable lowering of production costs. At the same time, rf heating has enabled many firms to produce designs that would not have been possible by other methods, as well as giving a better finish to the completed product.

Among the important contributions which British electrical engineers have made in this field is the introduction of the 'stray field platen' to the woodworking industry, a development which allows firms who have no specialists in rf heating to employ this system successfully. Britain was also the first country to use the double tier tray system for lipping chipboard, which reduces the amount of floor space needed for the operation and has the still more important result of reducing the operator's non-productive time to a minimum.

The glues which are being used by the largest number of firms in the wood trade are those known as synthetic resin adhesives. These adhesives, which will give bonds as strong as the wood itself, have the property of curing more quickly as their temperature is increased. A typical glue which takes four hours to become solid at a temperature of 60 deg F (15·6 deg C) and give a reasonable bond in the joint, will give the same strength in 10 seconds when its temperature is raised to 220 deg F (104·4 deg C). It is in this raising of the glue temperature that rf heating can be of advantage by giving increased output with a limited number of jigs; also in many instances it applies the energy just where it is wanted—that is, in the glue line.

The basic principle of rf heating is that when a non-metallic substance—wood or wood and glue—is placed between two plates or electrodes across which there is an rf voltage, the mass will have its temperature raised. The heating effect H in the material is given by the formula

$$H \propto V^2 f \cos \varphi$$

where V is the voltage across the material, f is the frequency and $\cos \varphi$ is the power factor of the material.

From the above formula it can be seen that by increasing the frequency, the voltage across the material can be reduced to give the same heating effect. The frequency cannot be too high because of a number of factors which include the effect known as 'standing waves' and the difficulties of resonating the load circuit to that of the oscillator; thus a compromise has to be arrived at in determining the frequency of operation. The most usual frequency which is at present used by the majority of firms in this country is one of about 10 Mc/s, although for many countries abroad 13·56 Mc/s has to be used to comply with local regulations. Fortunately the power factor (cos φ) of wood is such that it can be heated quite easily, its value being in the range of 0·05 to 0·3 depending upon the species of the timber and its moisture content.

In the basic method known as 'through heating', where the wood is between the two plates and the glue lines are in the same plane as the plates, the heating of the wood raises the temperature of the glue line and so reduces its curing time. This method of applying the rf energy is being used very considerably in making, for example, laminated assemblies such as bowed doors for furniture, parts for radio cabinets, as well as component parts for chairs.

The power factor of the average synthetic resin adhesive is high compared to that of wood, being from 0·8 to 0·93. Advantage can be taken of this by positioning the plates on either side of the glue line; the effect of this is that the temperature of the glue is raised more than that of the wood on either side of it. As it is the glue and not the wood which has to be heated, this method—known as 'glue line heating'—should be used

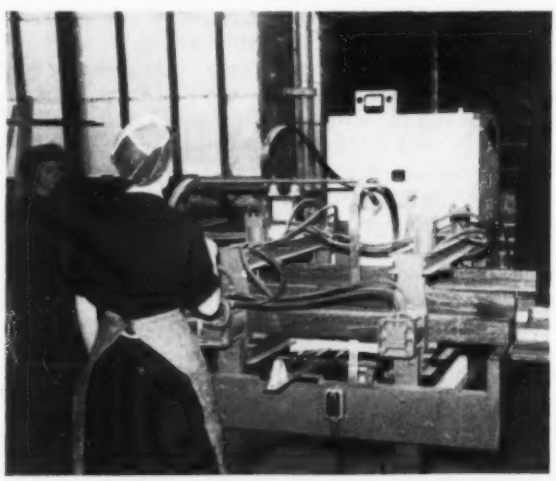


Fig 1. Operating a flush door lipping jig in which the thrusts are obtained from air cylinders, the framework being made from steel and wood. The operating time is six seconds for curing the glue on both the lippings. (Muirhead & Sons Ltd)

* Joint Manager, Pye Process Heating

herever practicable, as it is more efficient than through heating.

Although some of the rf energy does go into the wood on either side of the glue, the amount can be reduced by making the width of the electrodes as narrow as practicable; in some instances they are only $\frac{1}{8}$ in (3·2 mm) wide. When the glue line becomes wider the voltage across the electrodes has to be greater to give the same heating effect or curing time of the glue. This higher voltage necessitates more insulation between the electrodes and the metal parts of the jig or press; there is also a greater tendency for the energy to go to other parts of the assembly instead of following the glue line. In practice the maximum width of glue line is taken as $3\frac{1}{2}$–4 in (89–102 mm) unless the rest of the assembly is well insulated with a material such as polythene.

Fig 1 shows a typical glue line heating application where flush doors are being lipped; the two glue lines which are each 78 by $1\frac{5}{8}$ in, 253 sq in (198 cm by 41·3 mm, 1632·2 cm²) are being cured with a 6 kW generator in as short a time as six seconds. When the moisture content of the wood in the door or that of the lippings becomes greater than 14 per cent, the power factor of the wood rises so that it takes more of the energy, leaving less for the glue and so increasing the curing time. For consistent results with the glue line heating method, it is essential that the wood on either side of the glue line should never exceed the value at which the time cycle was determined, otherwise the glue will not be properly cured.

Recommended Pressures and Curing Times

With a short curing time the temperature of the glue will be raised well above the normal boiling point of water, and when the water in the glue is allowed to boil the result will be a foamed glue which has little strength. To overcome this boiling, the glue line has to be under sufficient pressure to raise the boiling temperature of the water in the glue above that required to cure the glue in the time desired. In practice the minimum pressure advocated is 25 lb/in² (1·75 kg/cm²) when the curing time is 30 sec or more, but for faster times (which means that the temperature is higher) the pressure has to be greater, and up to 50 lb/in² (3·5 kg/cm²) with a boiling temperature of 295 deg F (146 deg C) has to be used.

Another example of glue line heating is the chipboard lipping press. In this case, the edges of the chipboard are of open texture and therefore most of the glue cannot be under pressure. As fast curing is desired, all the glue should not be cured with the rf energy, otherwise it would all boil. This can be overcome by curing only a percentage of the glue with the rf energy, the remainder being allowed to set on its own after the assembly is removed from the press.

The basic arrangement of this method is that the upper electrode is in the form of strips at the correct spacing and placed at an angle of 45° to the front of the installation, while the lower electrode is a full sheet of aluminium. With this system only the glue below the strips is cured; as the rest has no voltage across it, it does not have any heat generated in it. Although the strips are satisfactory they have to be connected up individually and there is a possibility that bad contacts can occur. The more practical method is to make the upper electrode from expanded aluminium, when only the glue under the solid part of the electrode is heated, that under the spaces remaining cool. This gives the same result as the strips but is much easier to manufacture and connect up.

Fig 2 shows clearly the construction of a press using the double tier tray system mentioned in the introduction to this article. The trays go under the upper electrode alternately, so that while one is being cured the other is being unloaded and reloaded. If, however, the lower electrodes were incorporated in the trays, connexions would have to be made to them and this could add complications to the installation.

This difficulty is overcome by splitting the upper expanded metal electrode and connecting each half to the terminals of the generator. This means that the lower plate is not connected to the generator at all and therefore only requires to be insulated from the tray, so that any movable connexions are eliminated. Another advantage is that the capacitance of the electrode assembly is only one quarter of what it would be if the top electrode had not been split, and this feature makes both matching and tuning considerably easier.

As the output from the generator is nearly balanced, the plate in the tray is at a potential only a little above earth and so requires only a small amount of insulation, thus allowing the tray to be smaller and lighter and making it easier to move.

Fig 2. A chipboard lipping press, showing the two movable trays, each of which can be lifted alternately against the top electrode assembly by hydraulic rams to give the top pressure, side pressure being pneumatic. (*Herbert E Gibbs Ltd*)

The horizontal pressure on the assembly is obtained by the inflation of air hoses which are placed around the sides of the tray and are made flat by means of springs when the air is removed. Top pressure on the assembly is obtained by hydraulic rams which lift the tray against the top electrode assembly, this pressure being necessary to ensure that the component parts are level before the glue

is cured and also that the electrodes are in contact with the glue lines or lippings.

A third example of glue line heating is the 'edge jointer', as shown in Fig 3, which is used for jointing narrow strips of timber to make wide boards. In this equipment the horizontal pressure is required in only one direction and a down pressure to keep the strips flat; thus the wood can be slid into the jointer at one end and out at the other end when the glue has been cured. The electrode arrangement can be a plate at the top and bottom; this will cure the glue between the strips satisfactorily but will also heat all the wood slightly. If the rf energy cures sufficient of the glue to hold the strips in close contact, the rest can be allowed to set on its own, thus allowing a lower powered generator to be used.

The Split Electrode

In the equipment shown in Fig 3, the upper electrode is of expanded aluminium sheet and will cure about 33 per cent of the glue, a percentage which has been found to be sufficient for practical purposes. This means that the power of the generator has to be only one-third of that needed for curing all the glue, thus making the installation much cheaper and at the same time reducing the running costs. As the areas involved are relatively large—6 ft by 3 ft (182 by 91 cm)—capacitance will be high between the bottom and upper electrodes for the average thickness of timber. This capacitance can be reduced to a quarter by splitting the top electrode into two halves and connecting each half to the terminals of the generator. This lower capacitance simplifies tuning and allows the timber thickness to be varied considerably without bringing the capacitance outside the range to which the installation will tune.

By curing only one third of the glue with this electrode arrangement, boards up to 6 ft by 3 ft (182 by 91 cm) made up of any number of strips can be produced in 50 seconds when using a 6 kW generator. If the electrodes had been solid sheets, a generator of at least 18 kW would have been necessary to cure the glue in the same time. The above times assume a timber moisture content of 14 per cent; if it were greater the wood would take extra power because of its higher power factor, leaving less for the glue and so needing a longer time for curing to take place.

The third method of applying the rf energy is that known as 'stray field heating', in which the electrodes are separated from the glue line by plywood or other material. As the glue for this application has a high power factor and is a relatively good conductor, the energy is attracted into it.

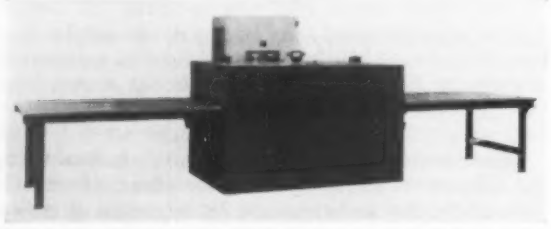


Fig 3. An edge jointer for making narrow strips of timber into wide boards both easily and cheaply. The loading table is at one end and the unloading table at the other. All pressures are pneumatic. (*Gibbs Constructor Ltd*)

The most popular method of using this system is the 'stray field platen' which is constructed from an insulating material and has the electrodes recessed into it. The electrodes are brass strips $\frac{3}{8}$ in (9·5 mm) or $\frac{1}{2}$ in (12·7 mm) wide, spaced at 2 in (50·8 mm) centres, alternate strips being connected to one bus-bar and the others to a second bus-bar; the bus-bars are connected to the terminals of an rf generator. With this platen there is an rf field under the whole of the area, so that any glue placed under it will be heated and so cured quickly. As the platen has to exert pressure on an assembly which may be veneered the electrodes could mark it, but this can be overcome by placing a thin sheet of insulating material between the platen and the work. An ideal material which will withstand both the heat and pressure is a silicone-bonded glass cloth. The advantage of this platen method is that once it has been tuned to the generator, no further tuning is needed whatever the size of the assembly being made or the area of glue line.

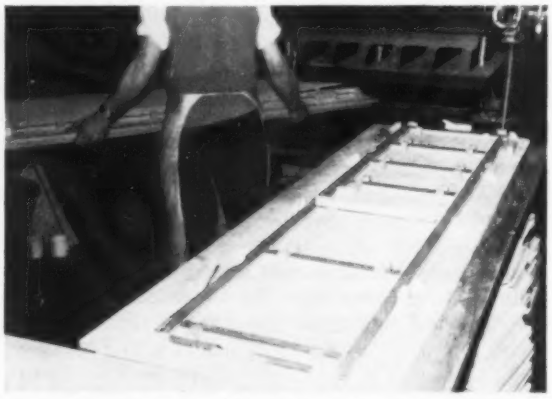


Fig 4. Inserting the simple locating jig beneath the stray field platen in a small daylight press. The next jig to be unloaded is on the right and is made solely from wood and strips of rubber. (*Fleetway Manufacturing Co Ltd*)

This method is proving popular in that it requires only simple locating jigs which can be made by any jig maker and he does not need any knowledge of rf heating; the jigs are also much cheaper than those which must incorporate the electrodes. Fig 4 shows a platen fixed to the top of a small daylight press and the loaded jig being placed in position. The field is at a maximum between the electrodes with a zero field below each electrode, and to avoid this zero field coinciding with the length of a glue line the electrodes are placed at an angle to the front of the platen. An angle of 45° gives the best results and the most even heating, and this is used by most manufacturers of these platens. Although their initial cost is relatively high, the saving in making the simpler jigs can easily pay for them in a few months.

Present-day equipments have been made simple in operation as the average user has no electrical knowledge and no basic theory of rf heating. The average equipment has a couple of switches for controlling the filaments of the valves and the ht for the power output; an automatic process timer to control the length of time the energy is on,

and a meter calibrated in either kilowatts or amperes to give an indication of the power output. Many generators incorporate a variable inductance to enable the load capacitance to be resonated to the frequency of the oscillator circuit. Thus by making the equipment simple, it can be operated by unskilled workers without any possibility of damage; furthermore, the time needed to set up for a new jig is reduced to a minimum.

The operating cost of such an installation is not only that of electricity but has to include depreciation of both the jigs and the generator, maintenance, servicing, and the replacement of the valves. Although the average valve in the generator is guaranteed for 2 000 hours they last for many thousands of hours, but for the initial costing only the guaranteed life can be considered, which will give the worst figure likely to be encountered. By depreciating the equipments over a period of 10 years and with electricity at 1d per unit and with the other factors mentioned above, a 3 kW unit will not cost more than 2s 3d an hour to operate when working for 40 hours a week and 50 weeks a year—2 000 hours a year. The figure for a 6 kW unit would be not more than 3s 6d an hour under the same conditions.

Many firms have found that they have been able to save enough labour and material when rf heating has been introduced into their factories to pay for the equipment within a year or so. In the lipping of chipboard without rf heating, the board has to be grooved along the edge and the lippings tongued, both operations using labour. With rf heating there is no need for this tongue and groove, which gives a saving in labour; as no tongue is needed on the lippings there is also a saving in material. Another advantage is that a butt joint gives the strongest bond but cannot be used without rf heating. The same saving takes place with the edge jointer; the narrow boards or strips can come direct from the straight line edger to the rf installation, as again no tongue and groove is advised.

The writer wishes to thank the firms concerned for allowing photographs of their installations to be used in this article and for the help he has received from them.

Annual Report of the ERA

THE annual report for 1958 of the British Electrical and Allied Industries Research Association has now been published and shows the wide field of research covered by the ERA. The work is carried out mainly in their own laboratories at Perivale and Leatherhead, but a large amount of cooperative and extra-mural research is done by national laboratories, universities and colleges.

While it is not possible to summarise the work carried out by all the departments there are some highlights that should be mentioned. One field which has probably the widest application in investigations into all branches of the electrical industry is that of insulation and dielectrics, and these activities exceed the available capacity of the section. Work is proceeding on problems associated with the breakdown of insulation due to the erosive action of discharges and on investigations into the properties of many new materials.

A new programme has been prepared for work on switch and control gear which will mean that new testing facilities will have to be made available. It is planned to build a new high power laboratory at Leatherhead, and a first estimate indicates that £370 000 will be needed for the transfer of plant from Perivale and for new and considerably larger equipment to tackle the problems set by the great increases in circuit-breaker rupturing capacity imposed by modern system developments.

The first stage of an investigation into the properties of steam up to 3 500 lb/in^2 (246 kg/cm^2) at 750 deg C has now been concluded and the results are being evaluated for publication at a later date. Experimental work on the second stage up to 15 000 lb/in^2 (1 055 kg/cm^2) is now in hand.

With the increase of power transmission at 200 kV and over, many new problems in protection against lightning need investigation, the performance at these voltages having been less satisfactory than was to be expected from methods of prediction which have proved satisfactory for lower voltage lines. The new ERA lightning flash counter has been most successful and is now in use in large numbers in many parts of the world. The instrument installed at Leatherhead recorded 1 858 lightning flashes in 3 hours during a thunderstorm in September last year.

Wind power has received a great deal of attention and close contact is maintained with the Danish Wind Power Committee. A 25 kW machine has been tested and is now erected in the Isle of Man where it is running in parallel with diesel-electric generators supplying a small network. The 100 kW set which was tested at St Albans is now operating in Algiers and during tests it generated 180 kW during one period.

An overseas liaison unit was established during the year in order to maintain close relations with overseas research organisations and to reinforce the ERA service to members in the Commonwealth.

Another valuable service is that of representation on national and international bodies. Thirty-one members of the ERA staff serve on 258 committees in Great Britain and on 22 committees of overseas organisations, and the fact that they provide 15 Chairmen is a measure of their professional competence and standing.

The Information Bureau and Library have dealt with a large number of unusual technical inquiries and the translation service was maintained. A total of 80 new technical reports were made available to ERA members and 50 reports were released for general publication.

Japan's First Nuclear Power Station

DETAILS can now be given of the 150 MW nuclear power station to be built in Japan by the General Electric Co Ltd in collaboration with Simon-Carves Ltd, news of which appeared in our May issue.*

It will be recalled that the design is based on a single reactor of the gas cooled graphite moderated type similar to those already being built for the British nuclear programme, but special interest attaches to the design of the Japanese station because of the measures taken to ensure the safety of the installation under earthquake conditions.

This potential hazard has made it necessary to adopt a new approach to certain fundamental aspects, and it is claimed by the GEC that the resulting design is fully capable of meeting the stringent requirements laid down by the purchaser (the Japanese Atomic Power Company) for the most sevcre conditions which could arise from this cause.

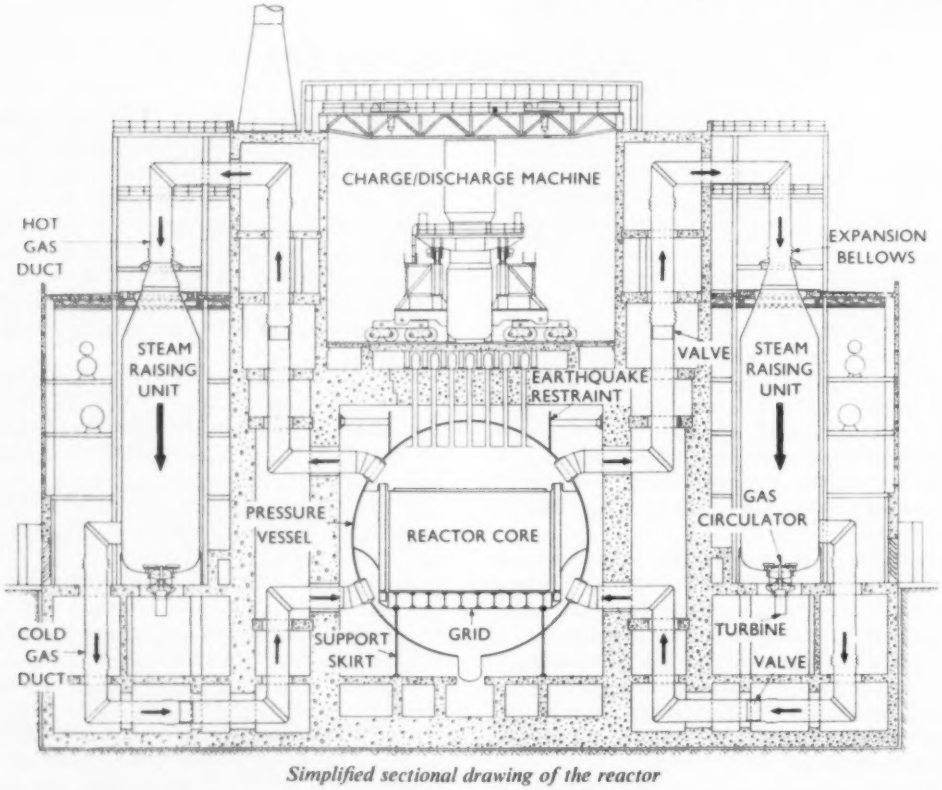
Structural Design and Plant Layout

One essential requirement in the structural design was to ensure the integrity of the reactor building and its associated steam-raising plant as a complete unit so that no breach could occur in the gas circuits. The concrete substructure supporting the steam-raising units is therefore carried on the main reactor foundation raft to ensure uniformity of movement during earthquakes. In addition, the support system for the gas ducts connecting the reactor pressure vessel to the steam-raising units has been designed so that the stresses in the ducts and in their junctions with the pressure vessel are maintained at safe levels under all circumstances.

As a further measure to ensure the safety of the reactor, the reactor building itself houses all the plant necessary to guarantee the removal of all heat generated within the core, even if severe earthquake shocks should cause the fracture of all pipe connexions between the reactor building and the turbine hall.

Reactor Core

The original core structure submitted to the Japanese Atomic Power Company was designed to accommodate dimensional changes due to thermal expansion and Wigner growth, and at the same time to withstand any conceivable earthquake hazard. Later experimental data confirmed, however, that at high temperatures and after long neutron irradiation a *shrinkage* occurs in the graphite. It had been appreciated that such shrinkage



Simplified sectional drawing of the reactor

* THE BEAMA JOURNAL, 66, No 2, page 50

would give rise to the possibility that under extreme conditions of emergency the outer part of the core might be held tightly together while the inner part could become loose. Studies had therefore already been commenced on various ways of overcoming this.

The GEC core design on which agreement has now been reached meets all the requirements without involving any loss of power output. The core is constructed solely of layers of graphite bricks, the bricks being basically hexagonal in section but keyed to each other in such a way that they remain fixed together in their correct relative positions under all possible conditions of expansion or contraction. A supporting structure surrounds the cylindrical core, serving to prevent the layers moving relative to each other even in the event of a severe earthquake.

Reactor Pressure Vessel

The spherical pressure vessel, 62 ft (18·6 m) in diameter, enclosing the reactor core is fabricated from steel plates 3·25 in (82·5 mm) thick, of a grade which has been specially selected to withstand the effects of prolonged irradiation.

The sphere is supported on a cylindrical steel skirt, and a further skirt welded to the vessel near the top is anchored to the biological shield as a precaution against disturbance during earthquakes.

Vertical standpipes connected to the top of the sphere pass upwards through the top shield and provide a means of access to the reactor core for the control devices and charge/discharge equipment. Further standpipes house mechanisms capable of detecting any displacement of the core, pressure vessel or support grid due to earthquakes and of shutting down the reactor before the safety of the installation is jeopardised.

Fuel Elements

There are 2 056 fuel channels each containing 8 fuel elements. The latter are fabricated from natural uranium metal encased in specially finned cans of magnesium alloy and each element is individually supported inside its own graphite sleeve, an arrangement originated by the GEC. The weight of the stack of elements in a channel is thus transmitted through the sleeves, so that stresses on the fuel rods themselves are kept to a minimum. By making the sleeves from a specially treated graphite which has a very low permeability to the coolant gas, it has proved possible to maintain the main moderator graphite at a temperature such that no significant storage of Wigner energy occurs during the life of the reactor.

Since the fuel in this reactor is charged and discharged from above, each element is provided with a grappling device which can be gripped by the charge machine grab. This device is made of a zirconium alloy and is designed so that the cartridge itself cannot be damaged during refuelling operations.

Charge/Discharge Equipment

In this reactor, the charging and discharging of fuel elements are carried out from above the reactor. Although GEC pioneered the development of bottom charge/discharge equipment—a feature which has considerable practical advantages—it was found desirable in this case to modify the design to meet the special local circumstances. By adopting top charging arrangements, the centre of gravity of the reactor building is lowered, thus improving its stability under earthquake conditions.

All normal refuelling operations are carried out with the reactor on full load and under pressure by a single machine travelling on a gantry above the top concrete shield. The same machine is also used for reactor servicing functions, including the planned maintenance of control mechanisms. A duplicate machine is installed to provide extra facilities during start-up and to permit the withdrawal of the first machine for maintenance.

Each charge machine is remotely controlled by a single operator from a desk housed in a control room at the edge of the pile cap. To ensure the correct performance of the machine's functions, highly developed sequence-control equipment is provided, the possibility of error being further reduced by the employment of a punched-card system for setting the requisite interlocks for any given operation. The operator can follow the working of the machine by means of mimic diagrams and closed-circuit television equipment.

Reactor Control Equipment

For all normal reactor-control functions, including emergency trips, the usual system of control rods is employed in which each rod is suspended from a stainless-steel wire rope wound on an electrically driven drum mounted in an extension to the associated top standpipe. The driving system provides accurate control of the rod's position in the core and of its rate of movement at all times.

In addition to the normal control rods, an alternative device which is completely independent of the control-rod system is provided to shut down the reactor in the case of an emergency, such as a severe earthquake. This system will operate even in the very remote possibility of the reactor core being greatly deranged by a violent earthquake.

Steam-Raising Units

Each of the four steam-raising units designed by Simon-Carves incorporates hp and lp evaporators with economiser and superheater sections. The banks of specially designed finned tubes which make up these various sections are mounted in a cylindrical pressure shell 84 ft (25·6 m) high and with an internal diameter of 21 ft 6 in (6·55 m). The tube supports and the skirt on which the complete unit is carried are designed to withstand earthquake shocks.

Gas Circulators

The carbon dioxide coolant is circulated through the reactor system by single-stage centrifugal blowers. One blower is mounted in the base of the pressure shell of each of the four steam-raising units, thus avoiding the need for large separate pressure casings. Each blower is driven by a steam turbine.

Generating Plant

In the turbine hall are two 85 MW turbogenerators each comprising a dual-pressure steam turbine driving a hydrogen-cooled alternator incorporating a highly developed system of direct cooling for the rotor. Apart from the normal steam condensers, dump condensing plant is provided for duty during start-up and shut-down. The circulating water for all this plant is drawn from the Kuji River.

New equipment and processes

New Buried Transformers of Larger Capacity
Distribution transformers designed for burying in the ground have been supplied by the *Hackbridge and Hewittic Electric Co Ltd* for many years, but the company has recently announced a new development in the form of an associated cooling unit above ground which makes much larger capacities available. The first of these new types has now been installed with the cooperation of the Eastern Electricity Board.

The equipment uses a standard oil-immersed core and coil assembly; the transformer is of 500 kVA capacity and has a voltage ratio of 11 000/433. Tappings are provided at ±2·5 and 5 per cent to a link board which can be reached through a hand hole in the lid.

The transformer assembly in its tank with horizontal incoming and outgoing cable boxes is buried directly in the ground on a concrete raft and the cooling radiator with built-in conservator is mounted on a frame located on the transformer tank so that the bottom of its case is flush with ground level. The outlet pipe from the radiator incorporates a standpipe so that the oil can be circulated or the tank emptied. The tank is made from heavy gauge steel and all buried structural parts are protected by an application of flame-sprayed zinc covered by a coating of bitumen.

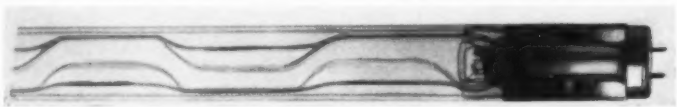
The radiator is a sectional type of normal design with cooling louvres on both sides of the case for adequate ventilation. A lockable inspection door gives access to the oil level gauge and thermometer on the conservator cover. The whole assembly is neat and compact, its height being only 4 ft 6 in (1·4 m).

Lowering into position one of the 500 kVA direct buried transformers described above

Units of smaller or larger capacity can also be supplied. The height of the radiator is constant but the length is adjusted according to the rating. If desired the transformer can be arranged in a shallow brick-lined cavity and buried up to its neck so that cable boxes and adjusting tappings can be conveniently reached. In addition the radiator can be mounted separately and off-set from the transformer within certain limits if the site makes this desirable.

High Efficiency Sodium Lamp for Street Lighting
A new sodium lamp giving 100 lumens/watt, to be known as the Mazda 200 W Sodium Linear, has been developed at the Leicester headquarters of the *AEI Lamp and Lighting Co Ltd* and is now available commercially, together with the equipment needed to use the lamp for street lighting. It is claimed to be the first practical lamp in the world to achieve an efficiency of 100 lumens/watt, representing an improvement of 25 per cent over any other practical light source known.

The simple tubular design of the lamp lends itself to a very robust construction, and crescent sections formed in the arc tube provide a directional output of light which is approximately one-third greater sideways than downwards, making the lamp particularly useful for street lighting.



The new Mazda 200 W high efficiency sodium lamp. It has a straight arc tube formed into a crescent section alternating to opposite sides over short lengths, a design feature which cuts down losses by arresting the migration of the metallic sodium

Designed with pre-heated electrodes, the new lamp does not require any high voltages. It starts and operates from 320 V, making it possible to use a control gear no bigger than that used for a conventional 140 W lamp. The control gear is tapped for supplies ranging from 200 to 250 V. The lamp starts and runs under extreme climatic conditions. As it operates at a low pressure, there is no delay in starting when it is switched on while still warm from use.

The luminous radiation is concentrated in the range from 5890 to 5896 Å, and a colour which may be described as monochromatic yellow. In addition to high luminous efficiency the lamp is stated to have exceptionally good life maintenance (92 lumens/watt average through life; 88 lumens/watt at 4000 hours).

The AEI 'Amberline' street-lighting lantern is an enclosed lantern specially designed for use with the new Mazda 200 W Sodium Linear lamp. It provides a medium-angle beam without cut-off and may be mounted at heights between 25 and 35 ft (7·6 and 10·6 m) and spaced at intervals of from 120 to 200 ft (36·6 to 61 m) according to the light required on the road surface.

The manufacturers expect that the introduction of this lamp and equipment will result in considerable changes in street-lighting technique. This high wattage light source makes it possible to light a road more brightly at less cost, with an additional saving in expense by a reduction in the number of columns used. It is claimed that lighting of twice the intensity can be provided with fewer columns for only 38 per cent greater cost. Alternatively, 31 AEI 'Amberline' lanterns mounted at a height of 35 ft (10·6 m) and spaced at 170 ft (52 m) will light a mile (1·6 km) of trunk road to a better standard than that provided by 44 traditional 140 W units mounted 25 ft (7·6 m) high and spaced at 120 ft (36·6 m).

New EMI High Performance Vibrator
A new environmental test vibrator specially suitable for high 'g' valve and component testing, extended fatigue tests, and accelerometer calibration is now being marketed by *EMI Electronics Ltd.*

Known as the EMV 100 A, this instrument has been developed to meet the need for a vibrator with a frequency range with full thrust extending to 20 000 c/s. The maker's specification states that the usable frequency range covers from 1 to 20 000 c/s and that continuous rating thrust is maintained throughout the range of 30 to 20 000 c/s.

The EMV 100 A offers 100 'g' peak, and when used with white noise and a peak-to-rms ratio of 3 to 1, the corresponding 'g' figures are 212·1 'g' peak and 70·7 'g' rms. The instrument, which is completely self-contained, is stressed to give over 100 per cent safety factor under these conditions.

Other features claimed include: response linearity unloaded (nominal) 35 c/s—Q=2; 80 to 2000 c/s—$\begin{matrix}+20\\-0\end{matrix}$ per cent; 5500 c/s—Q=30; 12 000 c/s—Q=16; 18 000 c/s—Q=7; anti-resonances—none; continuous rating thrust of 120 lb (55·4 kg) is maintained throughout the range of 30 to 20 000 c/s. Maximum random table acceleration due to the cooling medium is less than 1 'g' rms.

During reliability trials the vibrator is reported to have performed 1000 million reversals at 100 'g' level fixed frequency, and 1000 million reversals while the frequency was swept from 100 to 5000 c/s at 100 'g' level. It also carried out 200 million reversals at 500 'g'. The reliability trials are being continued in an endeavour to determine the life of the component parts. So far, says the company, no failures have been recorded.

Coal Face Signalling Coupler

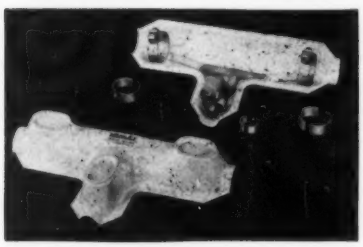
The Victor system of coal-face signalling has been developed by *Victor Products (Wallsend) Ltd* in conjunction with mining officials to meet the need for adequate signalling arrangements along the working face brought about by the increasing mechanisation of the mining industry.

In this system, three strengthened electrical conductors are embodied in a steel rope of 0·5 in (12·7 mm) diameter similar in construction to a haulage rope and making an extremely robust cable of greater strength than a normal armoured type. Short lengths of this cable are connected by restrained type quick-release plug and socket couplers, each of which incorporates a push switch which connects two of the conductors together for signalling purposes. The push button is provided with a lock-in feature so that in an emergency the face machinery can be stopped and will remain stopped until the face-worker is ready to allow the operator to restart, and in the meantime no other face-worker can inadvertently cause the machinery to start until the first man is ready.

The couplers can be used on either two or three wire circuits, and an important feature is their rapid disconnection for moving forward or for replacement. They are spaced at about 12 ft (3·6 m) intervals to allow signal points to be within easy reach of face workers. Victor couplers are designed for any low-voltage or intrinsically safe signalling circuits and can be used in conjunction with either audible or visual signals.

Plastic Joint Boxes for PVC Cables

The increasing use of PVC insulated wire armoured cables for low- and medium-voltage installations has led *W. T. Henley's Telegraph Works Co Ltd* to investigate the most suitable type of joint for these cables and to design a range of joint boxes manufactured from PVC and used with Henley cold-filling compound. The range covers straight-through, service and branch boxes for cables up to 0·30 sq in (194 mm²).



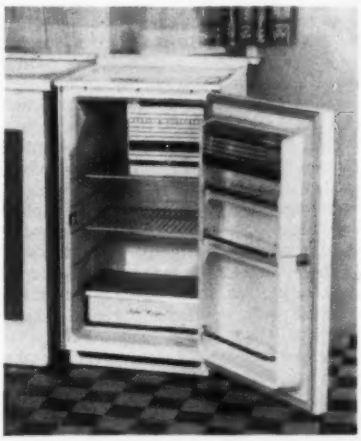
The Henley plastic joint box before assembly, showing the copper bonding and clamping rings

The boxes are moulded from PVC sheet in two halves which are stuck together with adhesive to form a complete shell when jointing is completed. The top half is provided with compound filling holes with press-in covers.

For straight-through and branch joints, normal sweated type connections are recommended, but for service joints a new type of mechanical connector has been developed which dispenses with the use of solder and heat.

To ensure continuity of the armouring, copper bonds with combined clamping rings are supplied which securely grip the armouring wires.

The Henley cold-filling compound which is used for filling the boxes is readily mixed cold, and adheres effectively both to the PVC insulated cores and to the PVC box itself.



The new English Electric 'Slimline' refrigerator described below

The 1960 Slimline Refrigerator

Because of the demand for this type of refrigerator and in particular for the Slimline model introduced by the *English Electric Co Ltd* last spring,* this firm has introduced the 1960 model of the Slimline several months ahead of schedule.

Although the new model has a larger capacity than the earlier one—4 cu ft (0·113 m³) instead of 3·4 cu ft (0·102 m³), its overall dimensions are only 36 in (91·4 cm) high, 20¼ in (51·2 cm) wide and 22½ in (57·1 cm) deep, and the top is designed as a working surface. A new feature of the interior is the adjustable shelving; the rod-type shelves can be divided or reversed and used in slots at five different levels in the cabinet walls, giving a choice of 20 basic arrangements and—say the makers—a combination of 296 different storage patterns

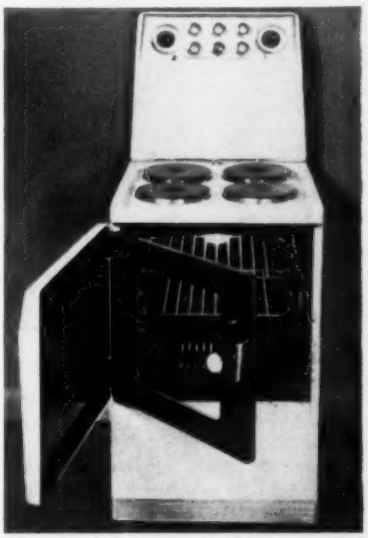
Other new features are the large enclosed evaporator which maintains the low temperature required for keeping ice cream and frozen food, and the salad crisper with full-width lid which also forms an extra shelf. Technical improvements to the unit have reduced running costs and have also made it scarcely audible when it is running. The cabinet is free from projections so that it will fit flush with other kitchen units and appliances, and the colour choice is white or cream exterior, with interior fittings and finish in shades of blue and gold.

The Creda 'Mercury Four' Cooker

Recently announced by the *Simplex Electric Co Ltd*, the new Mercury Four is a companion model to the Mercury De Luxe cooker introduced last year and described in the August, 1958, issue*. The Mercury Four has been developed for users who require a four boiling unit hob service, and it incorporates all the special design and performance features of the earlier model.

The four boiling units on the new cooker are the solid type Quick Discs which are a distinctive feature of the Mercury design. The Mercury Four has a new high splash-plate and control panel with clearly marked control knobs positioned to give easy access to adults and well out of reach of children. Automatic timer control and five-hour ringer dials are set in the panel on either side of the control knobs and the panel is finished with a chromium trim.

A departure from normal British cooker design is the position of the grill, which is housed in the roof of the oven and operates solely as a grill with consequently greater efficiency. As it is recessed in the oven roof, it does not reduce the oven capacity. The heated plate-warming drawer is a large one-piece pressing with well rounded corners; it is easily removed for cleaning and is operated by a separate control on the splashplate. The boiling plate controls are infinitely variable, giving any degree of heat required.



This view of the Creda 'Mercury Four' cooker shows the four Quick Disc boiling units, interior glass-panelled oven door and automatic oven light

The oven has a capacity of over 3000 cu in (0·049 m³) and is finished in a glossy jet black vitreous enamel. A draught-proof glass panelled interior door enables the cooking to be viewed without any loss of heat and an interior oven light operates automatically when either the main door or glass door is opened. The Mercury Four is finished in a tough impact-resistant enamel on the exterior panels and in high gloss acid-resisting vitreous enamel on the hob and splashplate.

Overall dimensions are 50 in (127 cm) high, 20 in (50·8 cm) wide and 23¼ in (59 cm) deep, and the total loading is 9300 W.

* THE BEAMA JOURNAL **65**, No 2, p 86

* THE BEAMA JOURNAL **65**, No 3, p 119

Book Reviews

General Circuit Theory. *By Gordon Newstead.* $6\frac{1}{2} \times 4$ *in* (165 × 102 *mm*). *Pp vii* + 144. *Index. Illustrated.* (*London: Methuen & Co Ltd*, 1959.) Price 15s net.

This is an addition to the publisher's 'Monographs on Physical Subjects'. The aim of the monograph is the development of an integrated treatment of electrical circuit theory. Unfortunately the author restricts the text to static networks, met mainly in the communication and allied fields of electrical engineering. The difficult and involved network problems met in rotating plant and power transmission are totally ignored.

The text of five chapters, illustrated by 45 line diagrams, discusses successively the basic concepts and theorems applicable to static linear networks, steady and transient state conditions, and finally a brief introduction to the extension of linear circuit theory to non-linear problems. The treatment is purely theoretical and there are no numerical examples or problems given to illustrate the application of the concepts. The author has however provided 28 references for further reading.

Most readers would welcome a discussion of the topology of networks, the difficulties associated with crossovers, the concurrent existence of both constant-voltage and constant-current generators and an introduction to network synthesis.

Although no prior knowledge is necessary, most readers without information will find the rate of development rather fast. There is an ever-increasing need for books, such as this, which generalise subjects at present dealt with piecemeal; for this reason the restriction of the text to light-current networks is unfortunate. Students should not specialise at the undergraduate stage.

P F SOPER

The Theory and Design of Magnetic Amplifiers. *By E H Frost-Smith.* $9 \times 5\frac{3}{4}$ *in* (229 × 164 *mm*). *Pp xix* + 487. *Illustrated. Index.* (*London: Chapman & Hall, Ltd.*, 1958.) Price 75s net.

The publishers have planned to issue a series of books on automation and control engineering and this one is the first volume. It is intended that the series shall be a comprehensive coverage of the subject suited to the needs of the control engineer who must have a good understanding of the principles of automatic control and also of the fundamentals of all other branches of engineering. That is something of a 'tall order' but, none the less, a necessary one.

The present volume is devoted to certain special components of control engineering, namely magnetic amplifiers, and it covers their theory and design, and their manufacture, performance and applications. Following a short introductory chapter on ferromagnetic fundamentals there are seven chapters on transductors, one on closed loop control systems, one on high-speed transductors and magnetic amplifiers, one on amplifier circuits, four on magnetic amplifiers, and one on magnetic modulators. All of these contain the requisite amount of information on theory, design, and applications as will enable the control engineer—the experienced man and the student—to reinforce or to gain a thorough understanding of the theory and practice of magnetic amplifiers with a view to their best selection and usage for the particular purpose.

The text contains a number of useful numerical examples and the more advanced mathematical studies have been relegated to appendices. The book is very well illustrated and it contains a list of references related to the individual chapters and the usual index.

This is an exceedingly good book, and if the others of the series match it the control engineer will eventually have a unique specialist library at his disposal. Whoever conceived the idea of the series is to be congratulated, not only on the idea itself but also on the choice of author for the first volume. The overall format of the book is in accordance with the publishers' usual high standard which adds to its value.

S AUSTEN STIGANT

Telegraphy. *By J W Freebody.* 10 × $7\frac{1}{4}$ in (254 × 184 *mm*). *Pp xii* + 738. *Illustrated. Index.* (*London: Sir Isaac Pitman & Sons*, 1959.) Price 80s net.

To say that a book is a successor to the work bearing the same title by the late T E Herbert is to set a high standard. This has been achieved, and the present volume is a really authoritative compendium of all that the word 'telegraphy' means in the British Post Office, as well as dealing with important systems and equipment in other places. The scope of the book extends beyond that of its predecessor because of many recent developments, and there can be no doubt at all that it will be the 'bible' of the subject for many generations of telegraph students, operators and engineers. The book has been written in a very clear and readable manner, and mathematics have been kept to a bare minimum throughout. Even in the chapter on Transmission Theory, the reader is led into the subject very gently.

The author is to be complimented on undertaking a tremendous task and completing it very succesfully.

J H J

Patents for Engineers. *By Laurence H A Carr and J C Wood.* $8\frac{1}{4} \times 5\frac{1}{2}$ *in* (222 × 140 *mm*). *Pp* 107. *Index.* (*London: Chapman & Hall, Ltd*, 1959.) Price 18s net.

This admirable guide to precept and practice covers rather more than the mere title indicates, for it includes matter relating to Trade Marks, Registered Designs, and Copyright in addition to Patents. The book is confined to British practice and its authors are respectively and as recited, a chartered electrical engineer experienced in Patent work and a barrister-at-law of Gray's Inn. Thus, both the engineering and legal requirements for patent and similar protection have been reviewed and set forth by experts, to the undoubted advantage of those having little or no knowledge of the subject.

Within the modest compass prescribed for the book, the authors give an outline of the British Patent system, the legal aspects of rights and actions at law, an account of the procedure to be followed from the initial preparation of the provisional application to the final granting of Letters Patent, comments on such features as validity, infringement, Crown user, and the private inventor, a record of some historic patents, and a schedule of Patent Office fees. There are also short sections dealing with foreign patents, registered designs, copyright, and trade marks, as already mentioned.

The book offers very pertinent comments on patent agent-solicitor-barrister collaboration, on the often very vexed question of master and servant, licences, the Courts and many other matters too numerous to mention here but of which the would-be patentee should be cognisant. In particular, however, inventors should familiarise themselves with the provisions of the Patents Acts of 1949 and 1957 and reference to these is made in the book. The present reviewer has had an active professional engineering interest in patent affairs for many years as a result of which he has no hesitation in recommending this book as a first-rate account of its subject with practically no omissions of any moment.

S AUSTEN STIGANT

Higher Electrical Engineering. *By J Shepherd, A H Morton and L F Spence.* $8\frac{3}{4} \times 5\frac{1}{2}$ *in* (222 × 140 *mm*). *Pp x* + 566. *Illustrated. Index.* (*London: Sir Isaac Pitman & Sons*). Price 40s net.

This new book is intended to cover the subjects normally provided in a course for the Higher National Certificate in Electrical Engineering, and includes both power and light current topics. At the present time there is no available book which covers at the restricted level the range of work for this course.

The 21 chapters, illustrated with 328 line diagrams, cover successively symbolic notation, circuit theorem, bridge measurements, advanced three-phase theory, harmonics, transients, field theory, transformers, three-phase windings and fields, synchronous and asynchronous-machines, parallel operation, interconnected systems, surges and protection, electron dynamics, vacuum valves, amplifiers, feedback and gasfilled valves.

The text, written in a style popular with the type of student for whom the book has been prepared, presents a given topic and then follows it with one or more fully worked examples. There are in all 100 of these numerical examples. The treatment employs relatively simple mathematics

which do not extend beyond easy integrations. At the end of each chapter there is a number of numerical problems, 237 in all, by which the reader can test his progress: answers are given at the end of each question.

The authors have taken pains to use a uniform set of symbols and abbreviations, and the text employs the rationalised MKS system of units.

P F SOPER

Progress in Dielectrics. *Edited by J B Birks and J H Schulman.* 10 × 6¼ *in* (254 × 159 *mm*). *Pp ix* + 312. *Illustrated.* (*London: Heywood & Co Ltd*). Price 70s net.

This is the first of a projected annual series of volumes that is intended to present a critical international review of the subject of dielectrics. The seven essays contained in this work cover: Dielectric Breakdown in Solid Insulation; Directional Breakdown Effects in Crystals; the Electric Strength and High-Field Conductivity of Dielectric Liquids; Gaseous Dielectrics; Ferro-Electricity of Barium Titanate Single Crystals; Non-Oxide Ceramic Dielectrics; and Electrophoretic Deposition of Insulating Materials.

The subjects are treated in the main from the point of view of the research worker, and in general are well-written surveys. Each contains a good bibliography.

In spite of the excellence of the individual essays, it is open to debate whether any really useful purpose is served by bringing them together in book form. Almost inevitably a reader will find sections that are of little or no interest to him, and since the serious worker will have presumably kept in touch with the literature of the aspect of dielectrics in which he is interested, there is little point in summarising it for him. Books written on particular dielectric matters when sufficient material was available to justify their preparation would, on the whole, have been more useful than disjointed annual reviews.

J H J

Electron Physics and Technology. *By J Thomson and E B Callick.* 8¾ × 5¾ *in* (222 × 146 *mm*). *Pp xiv* + 527. *Illustrated. Index.* (*London: English Universities Press*, 1959). Price 50s net.

This new book on Electron Physics and Technology is one of the series on the Physical Sciences published under the general editorship of Sir Graham Sutton. While the aim of the new books in this series is still the provision of a strongly realistic approach to the physical sciences, they also endeavour to provide the reader with technical proficiency in the chosen subject.

The present volume comprises essentially two main parts. In the first section the authors claim to lay an adequate foundation of basic physical principles which will enable the reader to understand without difficulty the specific electron devices discussed in the second part.

The thirty-one chapters of this new book are illustrated with 291 line diagrams and discuss successively fundamental concepts of the free and bound electron, electron devices employing space charge variation, electron inertia, microwave devices, special purpose tubes, and finally materials and construction.

This book is on a very specialised subject and the detail is far beyond the needs of an undergraduate student. It is however one that a user of devices would read with interest. It would be of great assistance to a post-graduate student during an apprenticeship served with a firm making electron tubes. The authors have, however, overlooked a number of errors, some printing but others of omission or commission, which might mislead the uninitiated.

The text has been prepared with the minimum use of unnecessary mathematics, and the treatment presents physical concepts in a very readable manner.

P F SOPER

Principles of Electronics. *By M R Gavin and J E Houldin.* 8¾ × 5½ *in* (222 × 140 *mm*). *Pp xii* + 348. *Illustrated. Index.* (*London: English Universities Press*, 1959.) Price 30s net.

This new book on the Principles of Electronics is another in the new series on the physical sciences which are being prepared under the general editorship of Sir Graham Sutton. In preparing the text the authors have endeavoured to provide a general introduction to the subject of electronics suitable for students who are preparing for a first degree or diploma course in physics or electrical engineering. In the preface the authors state that the contents of the book provide the common background knowledge that should be acquired by a physicist or electrical engineer prior to specialisation.

The twenty chapters, illustrated with 315 line diagrams, discuss successively electron motion, electrons in matter, electron emission, types of thermionic and semi-conductor devices, voltage, power and transistor amplifiers, feedback, transients in amplifiers, direct-coupled amplifiers, oscillators, electrons and fields, special valves for very high frequencies, rectification, modulation and detection, relaxation oscillators and switches, wave-shaping and noise.

There are also three appendices on symbols, useful constants and a bibliography of nine references for further reading.

The authors have also wisely provided 247 examples for the student to test the knowledge he has acquired from reading the text; answers are given to the numerical questions.

In preparing the text the authors have taken care to concentrate attention on principles and fundamental concepts and have restricted the subject matter to what can reasonably be assimilated by all students who are following either a physics or electrical engineering course. The text is readable and includes topics now considered important for all electrical students, and the treatment is not made recondite by a mathematical approach. The level of mathematical knowledge required of a reader is little beyond that of the Advanced Level of the General Certificate of Education. The authors should give serious consideration in any future edition of the book to a fuller treatment of electron omission (thermionic, photo-electric and field), gaseous conduction and semi-conductor phenomena. The authors may, however, feel with the reviewer that these topics should be provided for this type of student in a special Physics subject; few engineers have a proper understanding of such basic conceptions.

This book is well recommended as eminently suitable for a course of undergraduate study.

P F SOPER

Electricity and Magnetism for Engineering Students. *By A W Hirst.* 8¾ × 6 *in* (225 × 152 *mm*). *Pp* 438. *Illustrated. Index.* (*London: Blackie & Son* 1959). Price 40s net.

Now in its third edition, this book has been completely revised and rewritten in terms of the MKS system of units. Many lecturers are now using the MKS system with little reference to the CGS system, with the result that future students may have little knowledge of the latter. With this in mind, the author has included an appendix explaining the fundamentals of the CGS system.

The subject has been presented from the engineering point of view rather than the physical. Its chief object is to prepare students to the standard of the University intermediate and National Certificate examinations.

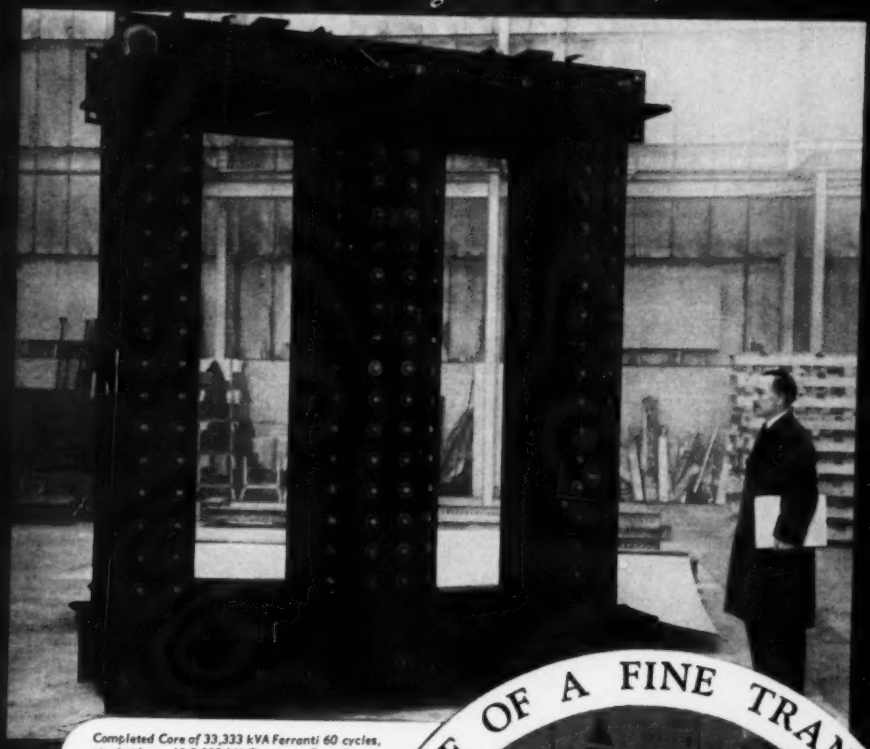
A summary of the common system of units and mechanical principles is given in the first chapter and the text then covers electricity, matter, and energy, the effects of an electric current and applications, magnetism and the electric circuit. Following chapters deal with thermo-electricity, electrolysis, electromagnetism, instruments and magnetic current calculation, which are very well explained. Only one chapter is devoted to the principles of electrical machines with the result that the treatment must be somewhat contracted, but it is quite sufficient for the purpose set out in the preface.

The subject of electrostatics has been placed at the end of the book; as the author says: 'although of great importance, it is of little value to the student until he has reached a more advanced stage'. The final chapter is concerned mainly with the consideration of the fundamental properties and characteristics of the diode and triode. Each chapter is followed by numerous examples with solutions at the end of the book.

The book was first published in 1936 and the popularity of the second edition (1946) can be judged by the fact that it was reprinted four times. It is a companion volume to the author's 'Applied Electricity' which has also been published in terms of the MKS system.

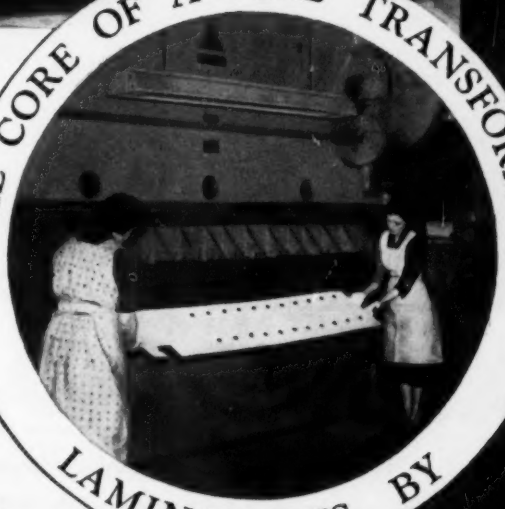
Index to Advertisers

	Page
Allen, W. H., Sons & Co., Ltd.	6
Allen West & Co., Ltd.	7
Arrol, Sir Wm., & Co., Ltd.	8
Associated Electrical Industries Ltd.	
Heavy Plant Division	Back Cover
Switchgear Division	9
Babcock & Wilcox Ltd.	14
Birlec Efco (Melting) Ltd.	11
Bolton, Thos., & Sons Ltd.	12
Bray, Geo., & Co., Ltd.	13
British Insulated Callender's Cables Ltd.	15
British Overseas Airways Corporation	10
Bruce Peebles & Co., Ltd.	16
Brush Electrical Engineering Co., Ltd.	18
Bushing Co., Ltd., The	17
Chloride Batteries Ltd.	19
Davidson & Co., Ltd.	20
Donovan Electrical Co., Ltd., The	12
Drysdale & Co., Ltd.	21
EMI Electronics Ltd.	22
EMI Sales & Service Ltd.	23
English Electric Co., Ltd., The	24
Evershed & Vignoles Ltd.	25
Falk, Stadelmann & Co., Ltd.	26
Ferranti Ltd.	27
Formica Ltd.	28
GWB Furnaces Ltd.	29
General Electric Co., Ltd., The	30-31
Hackbridge & Hewittic Electric Co., Ltd.	32
Heatrae Ltd.	33
Heenan & Froude Ltd.	44
Henley's, W. T., Telegraph Works Co., Ltd.	34
Hick Hargreaves & Co., Ltd.	35
Invicta Electrodes Ltd.	36
Ioco Ltd.	19
Lincoln Electric Co., Ltd.	38
M. & C. Switchgear Ltd.	42
MK Electric Ltd.	37
Mather & Platt Ltd.	39
Mawdsley's Ltd.	40
Metropolitan-Vickers Electrical Co., Ltd.	Inside Cover
Micanite & Insulators Co., Ltd.	41
Mirrlees Watson Co., Ltd., The	44
Nalder Bros. & Thompson Ltd.	43
Newton Bros. (Derby) Ltd.	44
Parsons, C. A., & Co., Ltd.	45
Permali Ltd.	46
Philips Electrical Ltd.	47
Pinchin, Johnson & Co., Ltd.	48
Pitman, Sir Isaac, & Sons Ltd.	19
Premier Cooler & Engineering Co., Ltd., The	54
Pye Ltd.	49
Redifon (Wandsworth) Ltd.	54
Reyrolle, A., & Co., Ltd.	50
Richardsons, Westgarth (Hartlepool) Ltd.	51
Sangamo Weston Ltd.	52
Siemens-Schuckert (Gt. Britain) Ltd.	53
Simplex Electric Co., Ltd.	56
Smith, Frederick, & Co.	55
Standard Telephones & Cables Ltd.	57
Sterling Varnish Co., Ltd., The	58
Thomas, Richard, & Baldwins Ltd.	1
Tudor Accumulator Co., Ltd.	35
Wakefield-Dick Industrial Oils Ltd.	2
Wiggin, Henry, & Co., Ltd.	3
Yorkshire Electric Transformer Co., Ltd.	4
Yorkshire Imperial Metals Ltd.	5



Completed Core of 33,333 kVA Ferranti 60 cycles, single phase, 13·2/230 kV Generator Transformer for Garrison Dam, U.S.A.

THE CORE OF A FINE TRANSFORMER



LAMINATIONS BY

LAMINATIONS
of all types, in all sizes and in all grades of material.

FERROSIL
hot-rolled and cold-reduced electrical sheet and strip, and hot-rolled transformer sheet.

ALPHASIL
cold-reduced oriented transformer sheet and strip.

RICHARD THOMAS & BALDWINS LTD.

RTB

Our Cookley Works is one of the largest in Europe specializing in the manufacture of laminations for the electrical industry.

LAMINATION WORKS: Cookley Works, Brierley Hill, Staffs. MIDLAND SECTION OFFICE: Wilden, Stourport-on-Severn, Worcs.
HEAD OFFICE: 47 Park Street, London, W.1

ILO service to transformer oil users

When you use ILO Electrical Oil, you benefit in three ways—from a product which maintains consistently high quality, from the advice of experienced technicians and from such facilities as this self powered, 1000 gallon/hour Mobile Filter Unit, for the treatment of degraded oil on site.

ILO **ELECTRICAL OILS**

WAKEFIELD-DICK INDUSTRIAL OILS LTD., 67 Grosvenor Street, London, W.1. GROsvenor 6050

Member of the worldwide Wakefield Castrol Organisation

HERE'S RELIABILITY FOR YOU

The reliability of Brightray materials is proved in exacting situations like these. The Brightray series includes suitable resistance alloys for most industrial and domestic purposes, including electric fires, immersion heaters, boiling rings and other appliances.

DE-ICING AIRCRAFT
The Rolls-Royce Dart engine intake in the Vickers Viscount is equipped with a Dunlop electrothermal de-icing system incorporating elements made from BRIGHTRAY S and FERRY.

SALT BATH HEATING
This immersion heater, for the exacting task of industrial salt heating, uses BRIGHTRAY C electrical resistance alloy. (British Thomson-Houston Company Limited).

BRIGHTRAY

NICKEL-CHROMIUM
Electrical Resistance Alloys

BRIGHTRAY C for intermittent heating up to 1150°C . . . used in cookers, toasters, laundry irons, fires, soldering irons . . .

BRIGHTRAY B for elements working up to 950°C . . .

BRIGHTRAY S for continuous heating up to 1150°C . . . mainly for electric furnace elements

BRIGHTRAY F for electric furnace elements operating in special atmospheres up to 1000°C

BRIGHTRAY H for furnace elements in the range 1100° to 1250°C (strip form only).

PRODUCED IN THE FORM OF ROD, WIRE, STRIP & TAPE

WILCO-WIGGIN THERMOMETALS in many grades for thermostatic devices controlling temperatures ranging from — 75 to 540°C

SEND THIS COUPON

for a copy of 'WIGGIN ELECTRICAL RESISTANCE MATERIALS'. Contains invaluable technical data.

NAME _____

APPOINTMENT OR DEPARTMENT _____

COMPANY _____

ADDRESS _____

_____

BJ

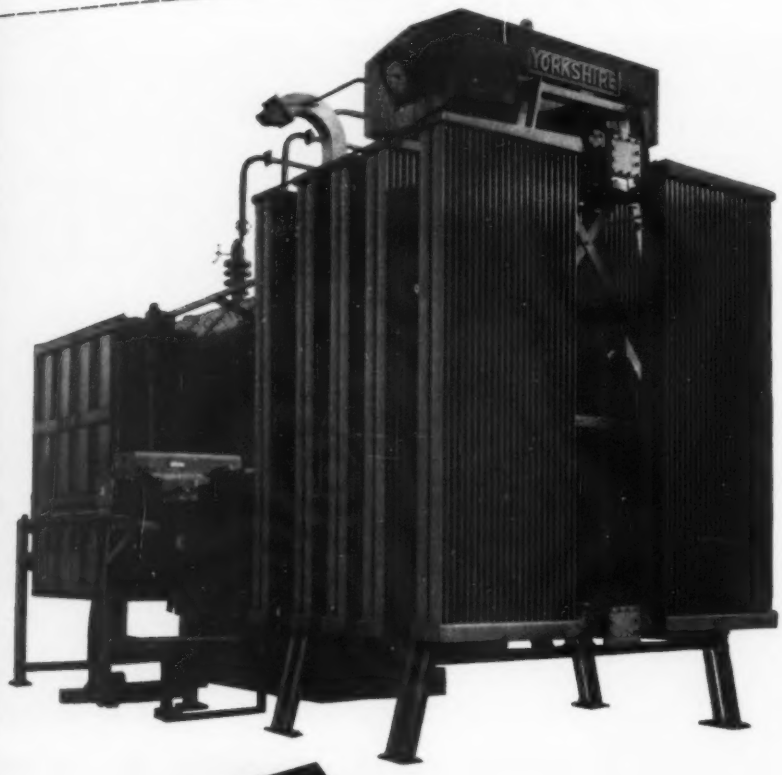
'BRIGHTRAY', 'FERRY' AND 'WILCO-WIGGIN' THERMOMETALS ARE REGISTERED TRADE MARKS

HENRY WIGGIN & COMPANY LIMITED · WIGGIN STREET · BIRMINGHAM 16

TGA 86

Y·E·T

Constructed by Careful Craftsmen



YORKSHIRE

transformers

We are specialists in the manufacture of **POWER TRANSFORMERS** for Generation, Transmission and Distribution. Every Transformer is entirely manufactured in our own works.

All sizes up to 75,000 kVA Voltages up to 150 kV

YORKSHIRE ELECTRIC TRANSFORMER CO. LTD
THORNHILL, DEWSBURY, ENG. *Tel.:* Dewsbury 1691-2

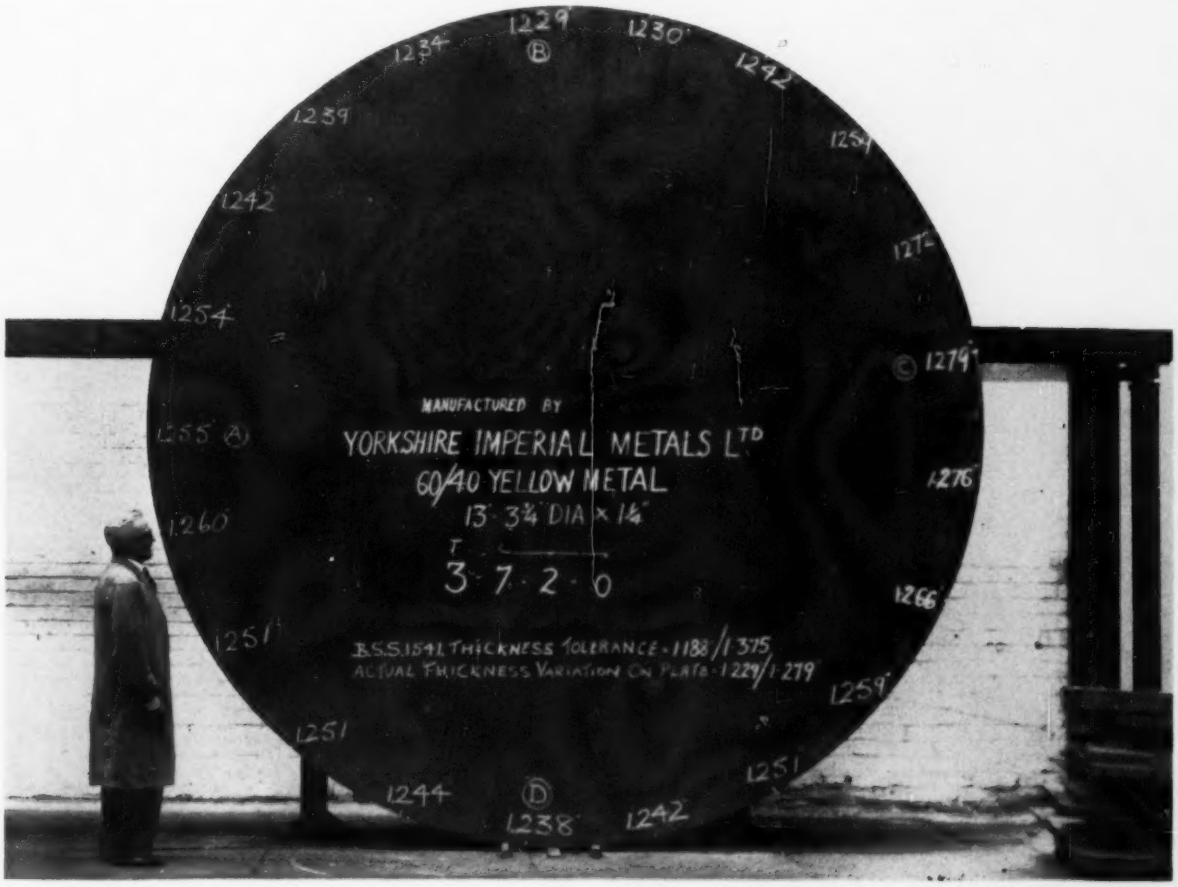
largest power station condenser plate rolled by

YORKSHIRE IMPERIAL

The photograph below shows the largest diameter land power station plate ever rolled in this country and is a typical example of the high standards achieved at the Landore Works of Yorkshire Imperial Metals Limited.

Strict control of the melting operation ensures consistently sound castings, whilst the rolling technique employed and the cutting to special designs minimise further machining at customers' works. Deviation from flatness and the thickness tolerances called for in B.S. 1541 and A.S.T.M. B171 are carefully maintained. For instance, for plates other than copper, up to 8 ft. in width, deviation from flatness does not exceed 0·015 in. in any 1 ft. length, whilst for plates over 8 ft. in width 0·020 in. in any 1 ft. length will not be exceeded.

Whether your requirements are for condenser plates, cooler, heat exchanger, copper or bi-metal plates, *Yorkshire Imperial* are able to serve you well—in the widest range of alloys.



YORKSHIRE IMPERIAL METALS LIMITED

HEAD OFFICE — P.O. BOX 166, LEEDS
TELEPHONE: LEEDS 7-2222

ALLEN ON THE MAP
in Southern Africa

The locations of some of the many ALLEN installations which are meeting the demand for power and water for a wide variety of industries and essential services in the Union of South Africa and the Federation of Rhodesia and Nyasaland.

ELECTRICITY SUPPLY **SALISBURY** PUMPING PLANT

WATER SUPPLY **SALISBURY** PUMPING PLANT

TIMBER **BLYDE SAW MILLS** STEAM ENGINE PLANT

ELECTRICITY SUPPLY **PRETORIA** PUMPING PLANT

ELECTRICITY SUPPLY **JOHANNESBURG** PUMPING PLANT

COAL MINING & OIL SHALE PLANT **TORBANITE** STEAM TURBINE PLANT

WATER SUPPLY **ZWARTKOFJES** PUMPING PLANT

WATER SUPPLY **VEREENIGING** PUMPING PLANT

ELECTRICITY SUPPLY **TAAIBOS** PUMPING PLANT

ELECTRICITY SUPPLY **HIGHVELD** PUMPING PLANT

ELECTRICITY SUPPLY **EMPANGENI** STEAM TURBINE PLANT

SUGAR **GLEDHOW, FELIXTON & AMATIKULU** DIESEL PLANT

ELECTRICITY SUPPLY **COLENSO** PUMPING PLANT

ELECTRICITY SUPPLY **DURBAN** PUMPING PLANT

ELECTRICITY SUPPLY **KEETSMANSHOOP** DIESEL PLANT

WATER SUPPLY **KIMBERLEY** PUMPING PLANT

ELECTRICITY SUPPLY **CAPE TOWN** PUMPING PLANT

WATER SUPPLY **BLOEMFONTEIN** PUMPING PLANT

HOSPITAL **NELSPRUIT** STEAM ENGINE PLANT

ELECTRICITY SUPPLY **OUDTSHOORN** STEAM TURBINE PLANT

ELECTRICITY SUPPLY **PORT ELIZABETH** PUMPING PLANT

WATER SUPPLY **EAST LONDON** PUMPING PLANT

ELECTRICITY SUPPLY **ALIWAL NORTH** STEAM TURBINE PLANT

ELECTRICITY SUPPLY **KOKSTAD** STEAM TURBINE PLANT

Specialists in complete Power Generating Plant and Pumping Plant installations

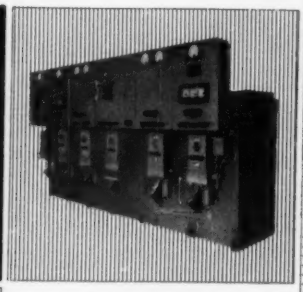
ALLEN PRODUCTS FOR INDUSTRY AND ESSENTIAL SERVICES

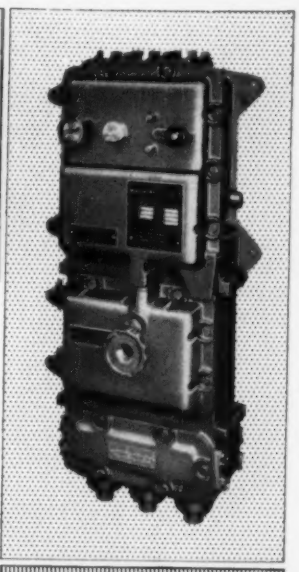
- DIESEL ENGINES
- STEAM TURBINES
- STEAM ENGINES
- GAS TURBINES
- CENTRIFUGAL PUMPS
- MIXED-FLOW PUMPS
- AXIAL-FLOW PUMPS
- CONDENSING PLANT
- ALTERNATORS
- D.C. GENERATORS
- A.C. & D.C. MOTORS
- A.C. & D.C. CONTROL GEAR
- SWITCHBOARDS
- EPICYCLIC GEARS
- PARALLEL-SHAFT GEARS

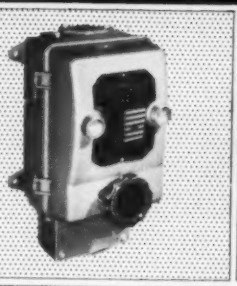
W. H. ALLEN SONS & Co LTD

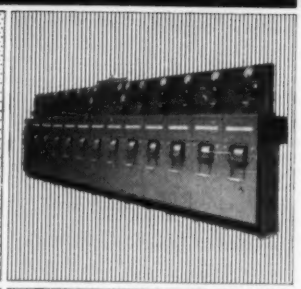
BEDFORD ■ ENGLAND

ALLEN WEST

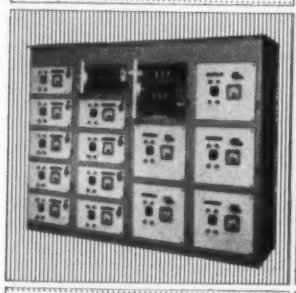


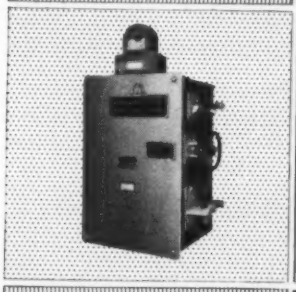


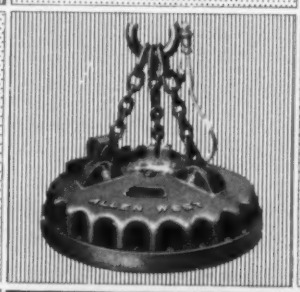


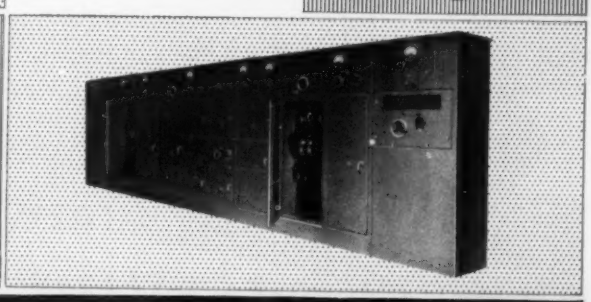


Electric Motor Control Gear





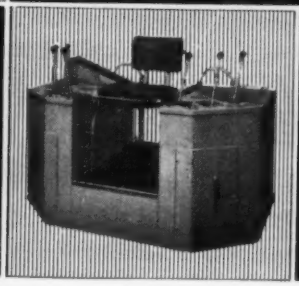




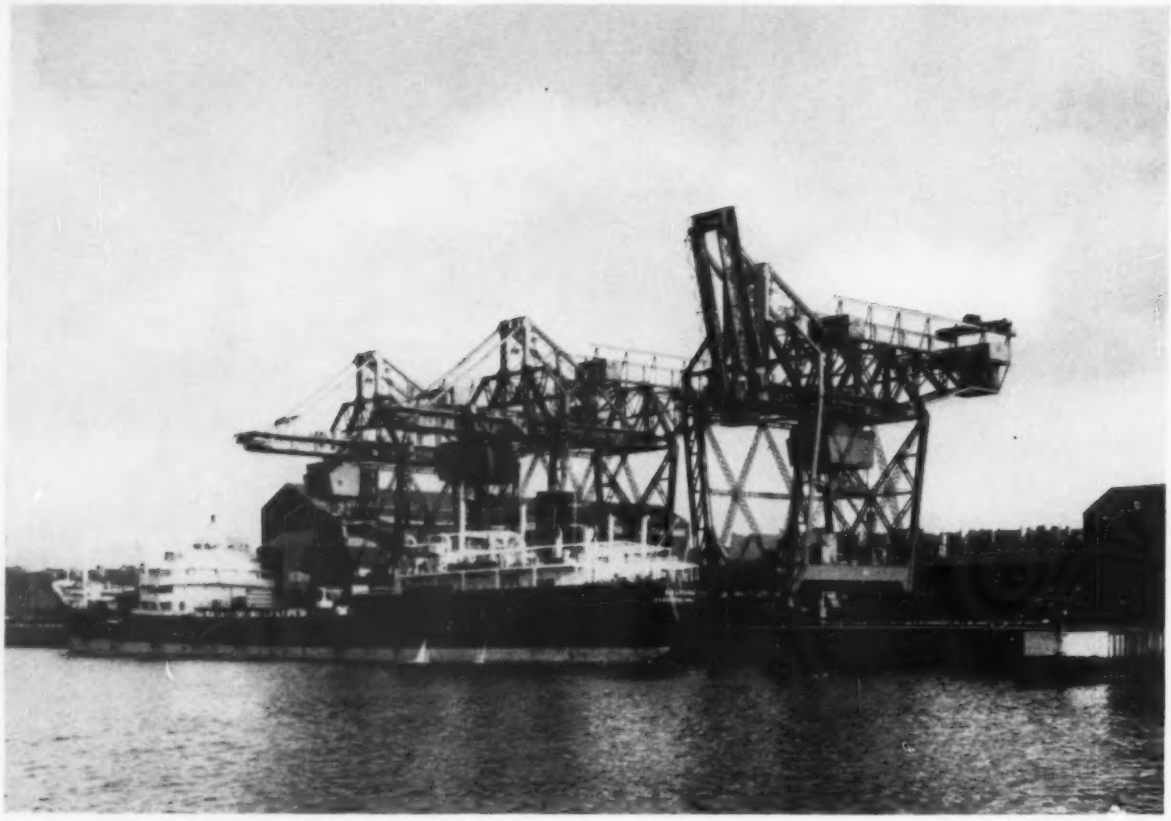
for every industrial application

ALLEN WEST & CO LTD
Brighton England

Engineers and Manufacturers of Electric Motor Control Gear and Switchgear



Subsidiary Companies in Canada, South Africa & Rhodesia
Agencies throughout the World



20 Ton Electric Travelling Ore Unloaders

Illustrated above are three 20 Ton Electric Travelling Ore Unloaders, built by Arrol at General Terminus Quay, Glasgow, for Messrs. Colvilles Limited. The machines have an outreach of 68 feet from the waterside rail and a combined maximum handling capacity of 1,800 tons of ore per hour, discharging on to a conveyor system.

Cranes and other Mechanical Handling Plant; all types of Steel Framed Buildings; Fixed and Opening Bridges; Dock Gates; Sliding and Floating Caissons; Compressed Air Locks; Hydraulic Machinery; Pipe Lines, Surge Tanks, Sluices and other equipment for Hydro-Electric Projects.

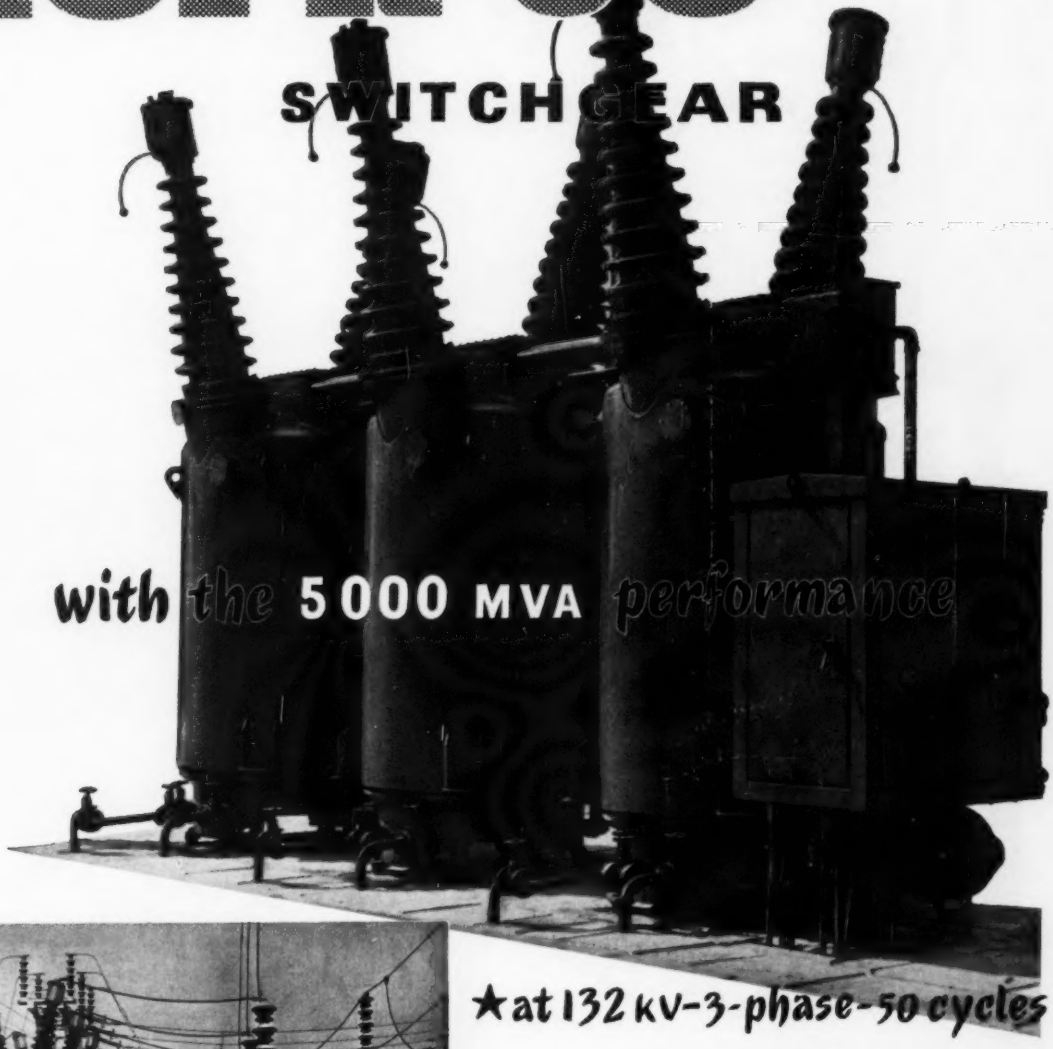
SIR WILLIAM ARROL & CO LTD GLASGOW

Arrol

TYPE

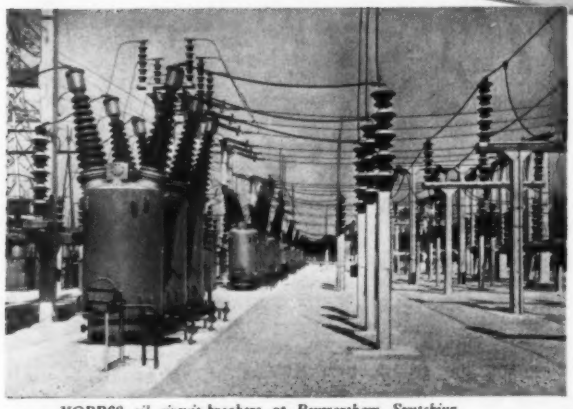
XOPR 60

SWITCHGEAR



with the 5000 MVA performance

★at 132 kV-3-phase-50 cycles



XOPR60 oil circuit-breakers at Penwortham Switching Station—N. West Merseyside & N. Wales Region C.E.G.B.

The challenge presented by the need for bulk-oil circuit-breakers capable of dealing with the higher fault levels now experienced through the 'Supergrid' has been adequately met by the introduction, at many points in the supply system, of the Type XOPR 60 circuit-breaker.

With its outstanding performance it is, without question, unique in circuit-breaker design, and suitable for service in varied climatic conditions.

AEI

Manufactured at the Higher Openshaw Works of

Associated Electrical Industries Limited

SWITCHGEAR DIVISION

Higher Openshaw, Manchester · Trafford Park, Manchester · Willesden, London

F779

B·O·A·C

gives your cargo jet-age handling

EAST

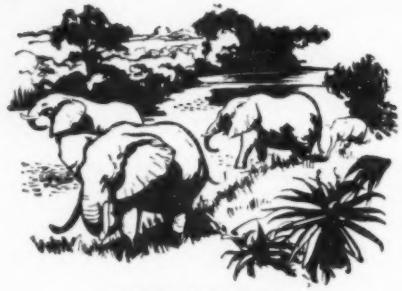
2 new BOAC all-freight services

Now—big extra capacity for your Eastbound air freight! BOAC and associate airlines operate 4 fast *all-cargo* services from London weekly, serving Rome, Athens, Beirut, Damascus, Karachi, Delhi, Calcutta, Rangoon, Bangkok, Singapore and Hong Kong. There are daily BOAC/Qantas services to Australia, soon including all-freight *Super-Constellations.*

WEST

Vast capacity by BOAC

Most comprehensive transatlantic cargo services by jet-prop *Britannias.* Daily departures from London, Manchester or Glasgow, serving New York, Boston, Detroit, Chicago and San Francisco . . . Montreal . . . Bermuda, the Bahamas, Caribbean and Venezuela.



SOUTH

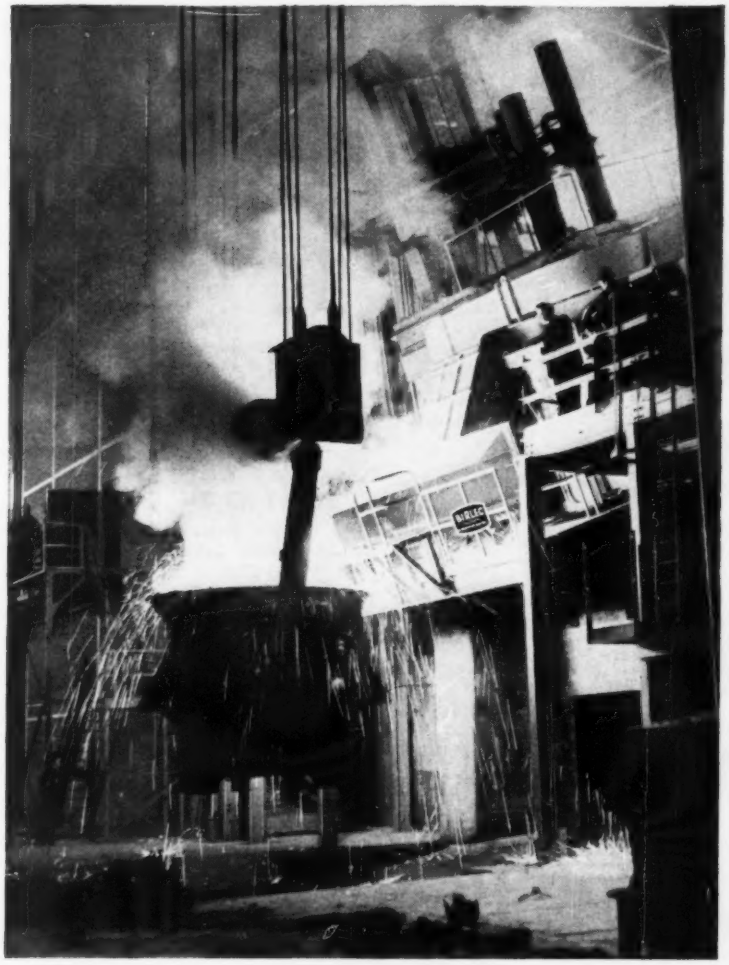
Jet-prop BOAC services to all Africa

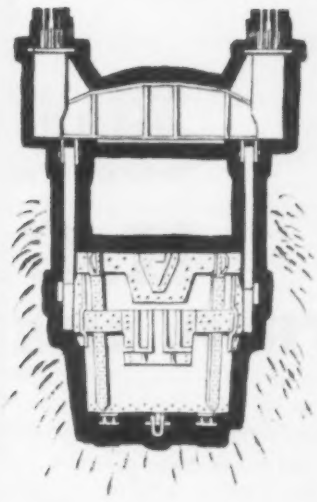
Next-day delivery to important points throughout Africa—thanks to speed, frequency and big cargo capacity of BOAC jet-prop *Britannia* services. For example, shipments from London can be in Lagos in 14 hours, Nairobi in 15¼ or Johannesburg in 22! BOAC offers fastest most comprehensive cargo services to Africa!

BOOKINGS AVAILABLE
TO ALL DESTINATIONS NOT DIRECTLY SERVED

For full details consult your local BOAC Appointed Shipping and Forwarding Agent or ring BOAC and ask for "Skyload" Service ***Unit.***

BRITISH OVERSEAS AIRWAYS CORPORATION WITH ASSOCIATE AIRLINES





ELECTRIC TONNAGE STEEL

Tapping one of the three electric arc furnaces installed in the new melting shop at Brymbo Steel Works Limited, Wrexham.

The three 16ft. electric arc furnaces installed at Brymbo Steel Works Limited, each rated at 12,500 kVA, have replaced the company's open hearth plant, an important departure from conventional practice. Though ordered from Birlec Limited before the amalgamation of their melting interests with those of Efco Limited, these units are typical of the Birlefco range of arc furnaces. Between them, the constituent companies have built more than 600 arc furnaces throughout the world, including every British installation exceeding 30 tons capacity.

BIRLEC-EFCO (MELTING) LTD

BIRLEFCO

WESTGATE
ALDRIDGE
STAFFS
Tel: Aldridge 52071

SM/BE/4871

BOLTON'S

H.C. COPPER

STRIP, SHEET, TAPE & FOIL

Plain and tinned; drawn, rolled, rolled and drawn, or rolled and sheared. Sheets up to 10 ft. x 4 ft. in any thickness over 1/32″; thinner sizes 6 ft. x 3 ft. or 4 ft. x 2 ft.

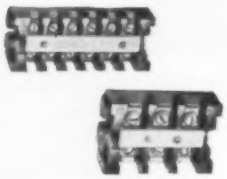
Annealed strip for generator and transformer windings, etc., with square or rounded corners, or with rounded edges; Bolton's specialize in the production, in suitable sizes, of long jointless lengths weighing up to 18 cwt. Hard-drawn and semi-hard-drawn strip in coils or in straight lengths; supplied in special tempers, to close tolerances, and on drums, when required. Foil down to 0.0005″ thick.

THOMAS BOLTON & SONS LTD

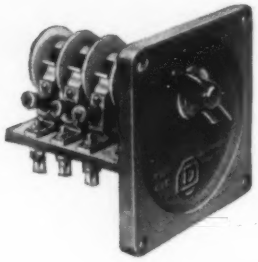
Head Office : Mersey Copper Works, Widnes, Lancashire.
Tel.: Widnes 2022.

London Office & Export Sales Department ;
168 Regent Street, W.1.
Tel.: REGent 6427.

Limit Switches (Type C32L 810/1) Plunger pattern with roller on end. Roller can be moved through 90 degrees and the switch can be altered from N.O. to N.C. on site.



Terminal Blocks (Type J96). Clamp type terminals. White marker strip, generous clearances between phases and to earth. Sizes available—15-amp. 550-volt. 3, 4, and 6-way. 30-amp. 550-volt. 3 and 4-way.



Flush-mounting T.P. Isolating Switch (Type C95) for building-in Machine Tools, etc. 30-amp. 550-volt.

a selection from a large range of

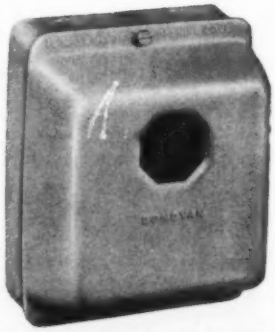
control accessories

by DONOVAN

THE DONOVAN ELECTRICAL CO. LTD.
GRANVILLE STREET . BIRMINGHAM 1

London Depot: 149-151 York Way, N.7

Glasgow Depot: 22 Pitt Street, C.2



A.C. Power Relays (Type A 11). Available 2, 4, or 8-pole (with one or two coil circuit change-over contacts), fine silver double-break main contacts rated at 10-amp. 550-volt. Any pole can be N.O. or N.C.

Illustrated is a 4-pole enclosed relay.

PAPER WRAPPING MACHINE · ATING · INCUBATORS · BAKERS' OVENS · CHEMICAL VAT · AIN MAIRIES · FOOD TROLLEYS ANTI-CONDENSATION HEAT · R BATTERIES · DEGREASING PLANT CANTEEN HOT CUPBOARDS · OIL BURNERS · BARREL HEATERS CALORIFIERS · GLASS PRE-H · G TESTING MACHINES · SPREADING AND CUTTING KNIVES · B · H SETTING · EMBOSSING · GOLD BLOCKING · MARKING AN · EATING · AUTOCLAVES · MIXERS GRAIN DRYING · SHOE SETT · NDENSATION FOR T.V. AND RADAR MASTS, SWITCHGEAR METE · RAILS · CROCKERY DRYING AND CURING · MELTING WAX, · MPOUNDS, TA · N. GLUE, PLASTICS, GREASE, CHEMICALS AND PETROLEUM JELLY · GRAIN DRYING · LAUNDRY MACHINES · AIRCRAFT SCREENS · SWITCHGEAR METERS PAPER WRAPPING MACHINES · DISH WASHING MACHINES · STEREO HOT HEATING · INCUBATORS · BAKERS' OVENS · CHEMICAL VAT HEATING · REFRIGERATOR DE-FROSTING · BAIN MAIRIES · FOOD TROLLEYS ANTI-CONDENSATION HEATI · BOTTLE WASHING MACHINES · AIR HEATER BATTERIES · DEGREASING PLANT CANTEEN HOT CUPBOARDS · ROTARY PRINTING PRESSES · STIRRERS · OIL BURNERS · BARREL HEATERS CALORIFIERS · GLASS PRE-HEATING · METAL AND WOOD GLUEING · BEARING TESTING MACHINES · SPREADING AND CUTTING KNIVES · BR · TES · P · SH · MBOSSING · GOLD BLOCKING · MARKING AND BRANDING · LAUNDRY MACHINES · PIPE HEATING · AUTOCLAVES · MIXERS GRAIN DRYING · SHOE SETTI · NYL · TES · G · AND ANTI-CONDENSATION FOR T.V. AND RADAR MASTS, SWITCHGEAR METERS, AIRCRAFT SCREENS AND RAILWAY SWITCH RAILS · CROCKERY DRYING AND CURING · MELTING WAX, M · S, CO · U · E, PLASTICS, GREASE, CHEMICALS AND PETROLEUM JELLY · FOLDING AND FORMING CARTONS, TRAVEL GOODS, PAPER. WOOD, LEATHER AND FABRICS MOULDING AND EXTRUDING THERMO-PLASTICS, RESIN BONDED FOUNDRY SAND, SYNTHENTIC AND NATURAL RUBBER · CROCKERY · BRIC · APER, WOOD, LEATHER AND FABRICS PAPER WRAPPING MACHINES · HEATING · INCUBATORS · BAKERS' OVENS · CHEMICAL VAT H · BAIN MAIRIES · FOOD TROLLEYS ANTI-CONDENSATION HEATI · ER BATTERIES · DEGREASING PLANT CANTEEN HOT CUPBOARDS · OIL BURNERS · BARREL HEATERS CALORIFIERS · GLASS PRE-HI · NG TESTING MACHINES · SPREADING AND CUTTING KNIVES · BR · USH SETTING · EMBOSSING · GOLD

BRAY

Supply Standard Electric Elements that apply the heat to a world of processes

You must read "Lights under Bushels" —our latest 20 page publication. We will gladly send you a copy on request.

GEO. BRAY & CO. LTD.
LEICESTER PLACE, LEEDS 2
Leeds 35399 (12 lines) Telex: 55186

All present and Correct...

AT BRITAIN'S HIGHEST EFFICIENCY POWER STATION

Right: Photograph showing megawattmeters at Castle Donington in June 1959, registering unit outputs of approximately 102, 100, 102, 99, 98, 99 megawatts.

102 100 102 99 98 99

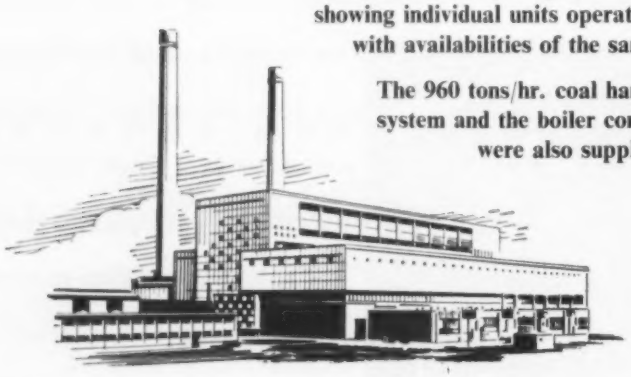
MEGAWATTS

WITH all its six 830,000 lb./hr. Babcock Radiant boilers on full load by June 1959, Castle Donington power station (C.E.G.B. East Midlands Division) was the first British station with 100 MW boiler/turbine units to come into full operation.

This station has also topped the efficiency table with an overall thermal efficiency of 32·9% and monthly averages reaching 33·33%.

The boilers have put up a first-class performance, available figures showing individual units operating at load factors over 90% with availabilities of the same order.

The 960 tons/hr. coal handling plant, the ash and dust handling system and the boiler control equipment for this outstanding station were also supplied by the Babcock organization.



BABCOCK
STEAM-RAISING PLANT

BABCOCK & WILCOX LTD, BABCOCK HOUSE, 209 EUSTON ROAD, LONDON, N.W.1

how Capacitors save power costs

AT KENFIG CARBIDE FACTORY

At the Kenfig Hill Factory of the Chemical Division of The Distillers Co. Ltd., calcium carbide is manufactured, the smelting of lime and coke being accomplished in three open arc furnaces.

Electricity supply is taken from the South Wales Electricity Board at 33 kV, and the scale of charges incorporates a penalty clause if the average monthly power factor is below .95 lagging.

The load was 55 megawatts at 0·84 power factor, and the installation of 18,000 kVAr of BICC CAPACITORS has eliminated the penalty, *resulting in a valuable annual saving on power costs.*

This capacitor installation — the largest industrial installation in Europe — consists of seventy-two BICC tank type 250 kVAr 6·35 kV capacitors housed in a specially constructed building.

Could BICC Capacitors save *you* money?

However large or small your installation, if you would like to know more about BICC Capacitors, please write for Publication No. 401. Our specialist engineers will be glad to survey your electrical system and, without charge or obligation illustrate how BICC Capacitors could cut your electricity bills quickly!

Write now! Every day, you may be paying more for your electricity than you need.

BICC
POWER
CAPACITORS

BRITISH INSULATED CALLENDER'S CABLES LIMITED, 21 BLOOMSBURY STREET, LONDON, W.C.1

BRUCE PEEBLES
EDINBURGH

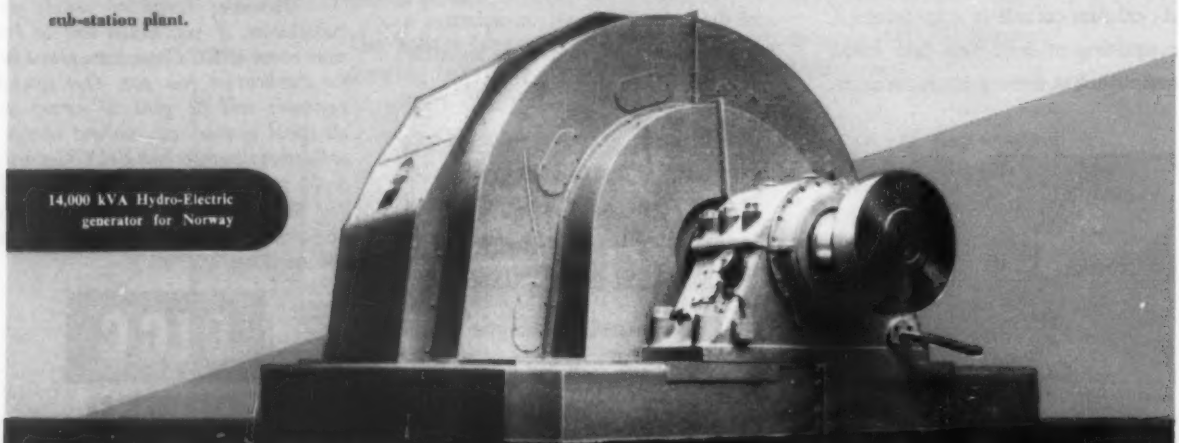
45MVA 132/33kV
transformer for England

Pioneers

OF THE ELECTRICAL INDUSTRY WITH OVER 50 YEARS' MANUFACTURING EXPERIENCE.

Activities embrace a wide variety of manufacture ranging from heavy rotating plant for the generation and conversion of electrical energy to motors for every sphere of industry: transformers of well over 100 MVA for 275 kV service to the smallest unit for distribution schemes and rural electrification; and complete rectifier sub-station plant.

For generations the name of Bruce Peebles has been famous for the manufacture of electrical power plant. Throughout its whole history the Company has ever been progressive, and its pioneering work has played an important role in the evolution of the present-day electrical age.

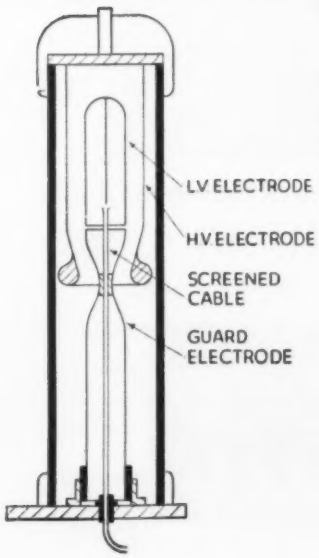


14,000 kVA Hydro-Electric generator for Norway

BRUCE PEEBLES & CO. LTD. EDINBURGH. SCOTLAND

4457

STANDARD CAPACITORS



The Bushing Co. Ltd. manufactures a range of compressed gas capacitors intended for use as comparison standards for the measurement of capacitance and dielectric loss factor. The capacitors are constant in value and virtually loss-free.

The gaseous insulant is dry, oxygen-free nitrogen at a pressure of 10 atmospheres and freedom from losses and invariance of capacity is ensured by the design and screening of the electrodes.

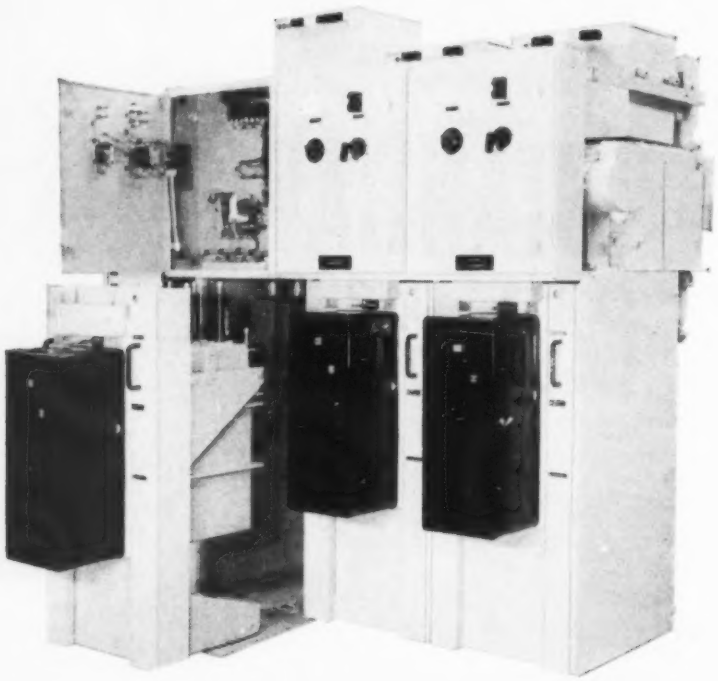
The sizes available range from 50kV to 500kV and both 50pF and 100pF capacitors are available in each size.

THE BUSHING COMPANY LTD.
HEBBURN-ON-TYNE, ENGLAND

Telephone: HEBBURN 83-2241
Grams: "BUSHING HEBBURN"

TEXOLEX

Accent on versatility.



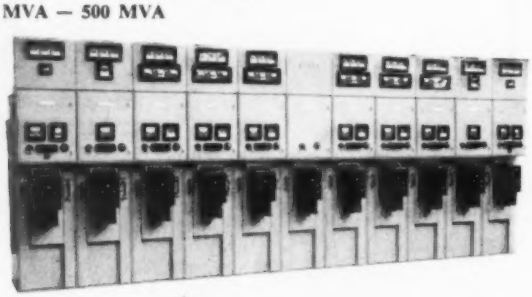
BRUSH

High Voltage Distribution Switchgear

Versatility is the key-note of this up-to-date equipment which is designed to meet the requirements of all modern Switchgear specifications including British Standard 116/1952. Its wide range of breaking capacities makes it suitable for many applications including high voltage distribution in electricity supply authority sub-stations, auxiliary supplies in power stations and many supplies in factories, steel mills, collieries, etc.

- Metalclad, unit construction, of either air-insulated or compound-filled, single or duplicate bus-bar types.
- Easily extended with switch-fuses and oil-switches for controlling transformers up to 750 kVA maximum capacity and ring main circuits respectively.

Range. Current ratings 400 to 1,600 amps. Voltage 2.2 — 11 kV
MVA ratings from 100 MVA — 500 MVA



Brush Electrical Engineering Co. Ltd. Loughborough, England *(Member of the Hawker Siddeley Group)*

S5.

NEW AND REVISED EDITION

THE PERFORMANCE AND DESIGN OF DIRECT CURRENT MACHINES

By ALBERT E. CLAYTON, D.Sc. (Engineering) (Lond.), etc.

Third Edition revised by the author in collaboration with N. N. HANCOCK, M.Sc.Tech. (Manchester), etc.

Here is a new and completely revised edition of this standard work. Completely up to date, some of the changes include the use of the MKS system throughout, control and special machines sections extended, the chapter on insulation re-written, a chapter on eddy-current losses in deep armature conductors added, and new illustrations. Taken all round this is an essential textbook for students working for B.Sc.(Eng.) degrees, Grad.I.E.E., Higher National Certificates, and similar exams.
From booksellers, 40/- net.

PITMAN *TECHNICAL BOOKS*

Parker St., Kingsway, London, WC2

Switch on with confidence

IOCO INSULANTS

will carry the load

FLEXIBLE INSULANTS

For Motors, Generators, Switchgear, Cables

IOCO Limited manufacture Insulating Cloths and Tapes in Paper, Woven Cotton, Silk, Nylon, Terylene and Glass bases, to Thermal Classifications A, E, B, F and H, respectively, having high dielectric strength, good mechanical strength and resistance to flexing and abrasion.

RIGID INSULATION

Formapex Laminated Plastics are manufactured in paper and fabric base grades to meet all British Standard Specifications for Electrical Insulation and Mechanical purposes.

Please write for Technical Brochures

IOCO LIMITED

Anniesland, Glasgow, W.3
Scotstoun 5501/6

A new and important advance

by Chloride Batteries Limited

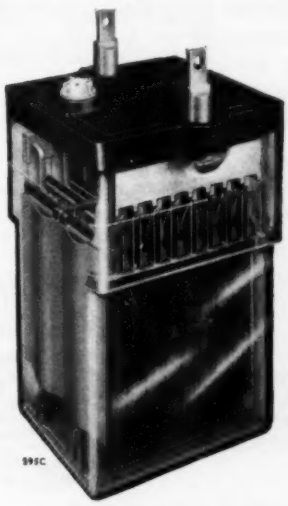
Stand-by power in

½ the space

FROM THE **NEW**

Chloride Stationary Cell

This new cell is specially designed for standby duties entailing discharge rates between, say, the 3-hour and the very high rates demanded for switch-closing purposes. With its Planté positive and pasted negative plates, Porvic microporous separators and many other improvements in material and in design, this light, robust cell will perform its duties with greater efficiency, with complete reliability and with a saving in battery space of approximately 50%. It is ideal for trickle-charge operation* and has all the remarkable length of life of the Planté type of construction. In Great Britain today standby batteries occupy millions of cubic feet of valuable space. The new Chloride cell could free almost half of it.

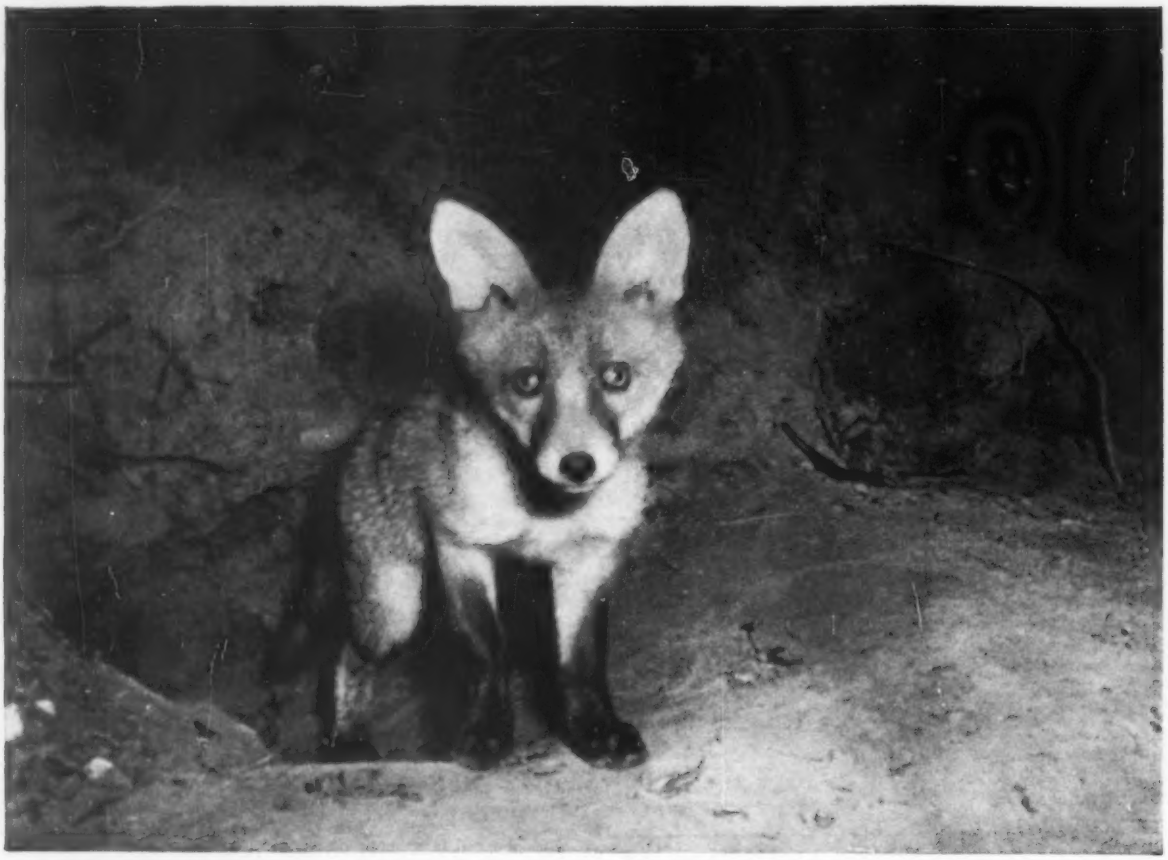


** The new cell will from now onwards be fitted in all Keepalite units—the Chloride Company's automatic emergency lighting system.*

By the makers of Exide Batteries

A PRODUCT OF CHLORIDE BATTERIES LIMITED
BACKED BY WORLD-WIDE SERVICE

Enquiries to: London, Elgar 7991; Bristol 64086; West Bromwich 2361; Leeds 20248; Glasgow, Bridgeton 3734; Manchester, Blackfriars 1158; Belfast 27953



First Steps

First steps are important in all walks of life, as this fox cub emerging from his parental "earth" is already instinctively aware. And if he takes the wrong turning he can land up in serious trouble.

In fan engineering, as in nature, the choice of the better alternative is rarely an easy one to make.

If you have in mind an application involving the movement of air or other gases, the name "Sirocco" is synonymous with a great deal of hard won experience that is freely yours for the asking.

You are invited, as a first step, to take advantage of our 75 years of experience and our unrivalled design, manufacturing and testing resources by contacting our nearest Branch.

Our Works trained engineers are at your service.

DAVIDSON & CO. LTD.

SIROCCO ENGINEERING WORKS
BELFAST, NORTHERN IRELAND (*Belfast 57251*)

London (*Whitehall 3541*) · *Manchester* (*Blackfriars 6210*) · *Glasgow* (*City 6786*) · *Birmingham* (*Midland 4916*) · *Newcastle-on-Tyne* (*26584*) · *Leeds* (*21886*)

by

DRYSDALE

for high efficiency and constant reliability

Service before sales

Our Research and Development department is constantly engaged on applied research in Fluid Mechanics and other branches of engineering science.
In addition every facility is available for the experimental investigation of problems directly concerning any specific pumping application. A fund of experience is available for customers' information ensuring the most efficient and economical pumping service.

After sales service

After sales service is an important function of the Drysdale organisation. An active staff of service engineers and technical representatives is available for short notice, free advice, on the spot service, to ensure Drysdale auxiliaries operate at peak performance.

DRYSDALE & Co Ltd
YOKER : GLASGOW

PUMP MAKERS FOR LAND AND MARINE SERVICES FOR OVER 85 YEARS

Driverless trolleys following wires laid on or under the floor, controlled from a central point — that's the E.M.I. Robotug system. Recently developed by E.M.I. engineers as a further aid to automation, the system has widespread applications in warehouses, airports, parcels offices and other goods handling centres, where it can increase efficiency and cut costs. Highly flexible, the system enables any number of trolleys to be operated over routes which can be rapidly varied to meet new needs. The electronic control equipment is robustly constructed to withstand heavy industrial use. Transistors are employed throughout to give utmost reliability and minimum drain on battery power supply. A foolproof safety device ensures that the Robotug is automatically halted immediately it comes into contact with an object or person in its path.

The Robotug - one of E.M.I.'s automatic control systems

E.M.I. also designs and manufactures automatic control systems for:
** Milling machines, lathes, grinders, boring and drilling machines * Conveyor belt route selection, and sorting * Formula mixing and batch weighing * Data recording and analysing * Electric motor Commutator Undercutting machines * Armature Testing and Dynamic Balancing machines * Vibration and environmental testing.*

EMI

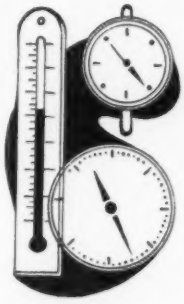
Please ask for full details, or a demonstration of any of these systems

E.M.I. ELECTRONICS LTD.

INDUSTRIAL DIVISION · HAYES · MIDDLESEX · TELEPHONE: SOUTHALL 2468

EE 51

extra help in the factory



By converting an electrical impulse magnetic tape can record temperatures, pressures, forces etc. . . .

With an E.M.I. tape recorder

Accurate recording of noise measurement aboard a moving vehicle.

Complete records of conferences and meetings.

Extra help . . . with today's intense competition in industry the use of magnetic tape recording is spreading with great rapidity. The ways and means by which it can help industry are numerous and cover many fields. Process Control, Machine Control, shock and vibration recording, noise measurement — in research of all kinds to record information accurately and fully ! Complete records of conferences, meetings easily made — and don't forget a vast amount of information can be kept on a little material.

E.M.I. — for over fifty years the world's leading exponents of sound recording and reproduction, produce recording equipment designed to satisfy the most exacting professional requirements.

MODEL TR90 — of unit construction available in rack mounted, console or transportable versions.

MODEL TR51 — (illustrated above) for " studio quality " whilst recording under mobile conditions.

MODEL L/2 — Lightweight battery recorder, compact, easy to carry and unfailing reliability under all climatic conditions.

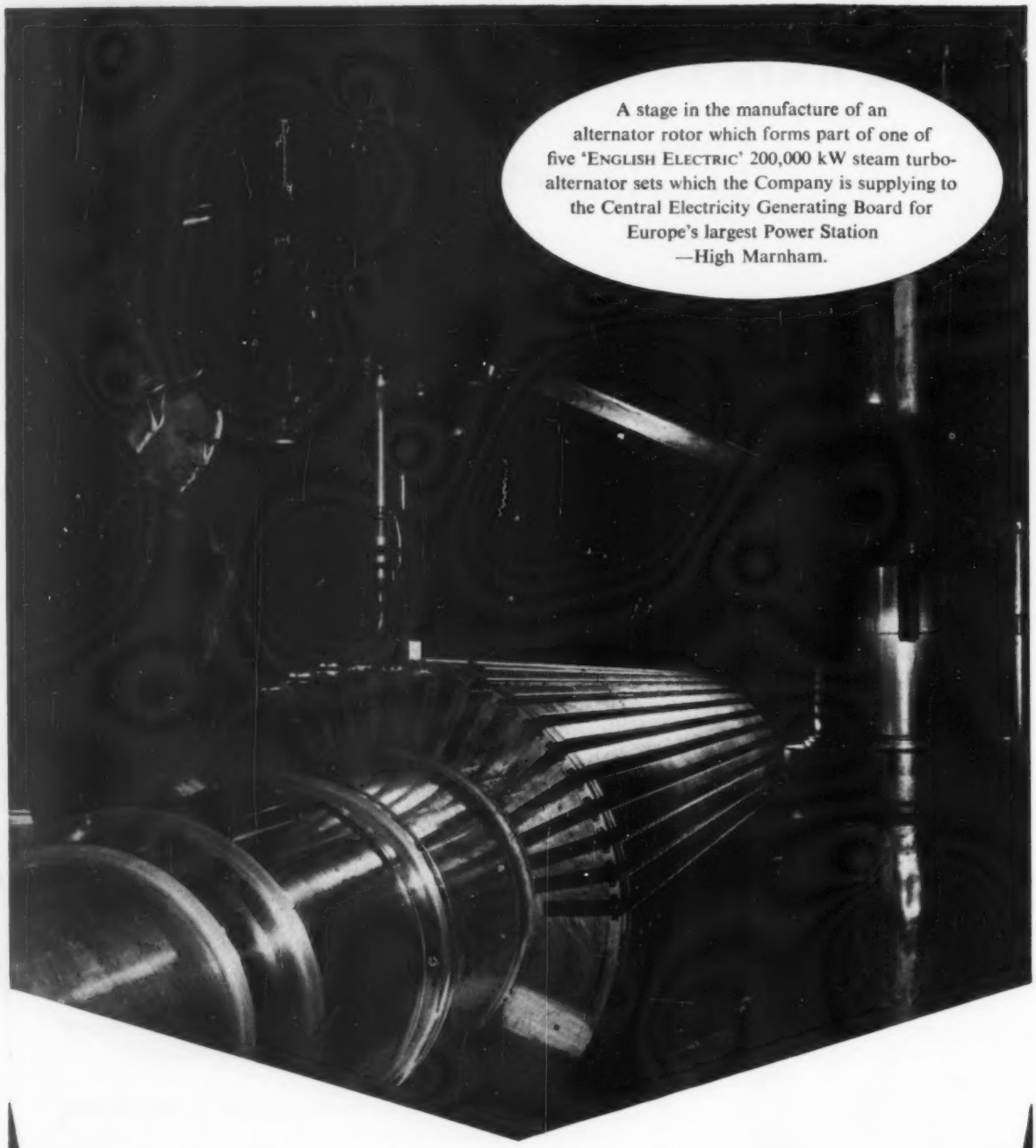
For further information write to :

E.M.I. SALES & SERVICE LTD.

(Recording & Relay Equipment Division

HAYES · MIDDLESEX · ENGLAND · Tel: SOUthall 2468

ES/P/1



A stage in the manufacture of an alternator rotor which forms part of one of five 'ENGLISH ELECTRIC' 200,000 kW steam turbo-alternator sets which the Company is supplying to the Central Electricity Generating Board for Europe's largest Power Station —High Marnham.

'ENGLISH ELECTRIC'

Power generation · Power transmission · Power control · Power distribution
Power transformation · Power conversion · Power utilisation · Power measurement

Power is our Business

THE ENGLISH ELECTRIC COMPANY LIMITED, MARCONI HOUSE, STRAND, LONDON, W.C.2

Partners in Progress with NAPIER, MARCONI'S, VULCAN FOUNDRY and ROBERT STEPHENSON & HAWTHORNS in The ENGLISH ELECTRIC Group

P.76

The NEW '59' DUCTER

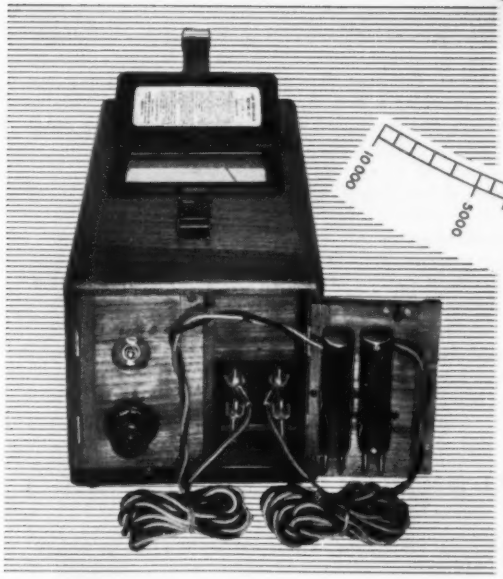
TRADE MARK

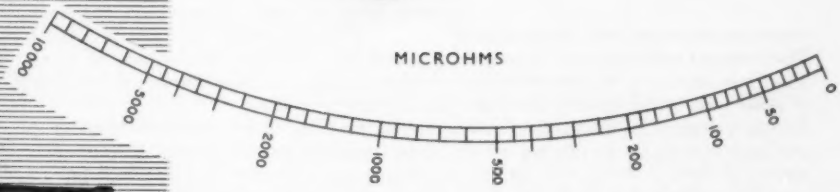
LOW RESISTANCE TESTING SET

Mains operated instrument. A similar battery operated instrument also available.

Compartment for leads and testing spikes.

In the battery model, this compartment contains 2 alkaline cells.





An entirely new, self-contained, direct reading testing instrument having a range of measurement from :

10 microhms to 1 ohm

provided by a 2-position switch (x 1, x 100).

Size 16¼ x 8½ x 8½ ins. Weight 26½ lb.

Write for Publication BB 051/16/17

EVERSHED *INSTRUMENTS DIVISION* **EVERSHED & VIGNOLES LTD · LONDON · W.4**

Telephone: Chiswick 3670 · Telegrams & Cables: Megger, London Telex 22583

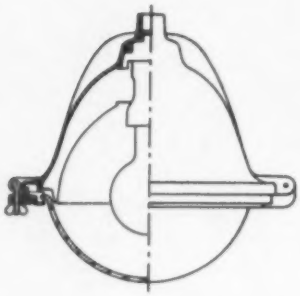
7/119

FALKS "GRENVILLE"

HEAVY DUTY CAST ALUMINIUM INDUSTRIAL LIGHTING UNIT

WEATHERPROOF, VAPOUR, DUST AND CORROSION RESISTANT

For use with 300 watt and 500 watt Tungsten filament lamps or 250 watt and 400 watt type MBF/U lamps



APPLICATIONS

The Fittings are especially designed for use where high angles of light are essential and where protection is required against weather or corrosive atmospheres. It meets the requirements of a variety of industries amongst which are the following:— Railway marshalling yards, Docks and Harbours, Cargo Loading, Gasworks, Chemical Works, Steelworks.

SPECIFICATIONS OF R.96720 "GRENVILLE" UNIT

The main body of the fitting (finned for heat dissipation) and the glazing ring is constructed from die-cast aluminium alloy L M 6 M, pre-treated from the "Alocrom" process prior to stove enamelling, one coat red oxide primer and two coats of corrosion resistant grey stove enamel.

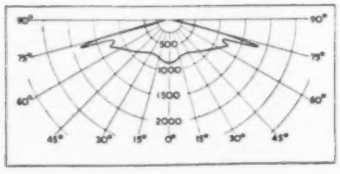
The internal reflector is of super-purity aluminium sheet anodically treated by the Brytal process.

The glass bowl is plain heat-resisting of robust section and a neoprene rubber gasket, of special section, seals the junction of glass with metal against the entry of moisture or fumes.

Positive alternative fixings for the lampholder are effected by a reversible carrier and instructions for its correct use are clearly marked on this carrier. The top of the main body is fitted with an anti-condensation device and the standard tapping for suspension is 1" B.S.P. Holes are provided in two of the fins if secondary suspension is required.

Access to the interior is provided by hinge and swing bolts, the hinge of the floating type permitting equal tension to be exerted on the gasket when the lantern is closed. The locking nuts are made captive on the swing bolts to avoid loss.

All external bolts, nuts and fixings are of stainless steel.



FALKS
FALK, STADELMANN & CO. LTD

91 FARRINGDON ROAD, LONDON, E.C.1
TELEPHONE: HOLborn 7654

Branches: BIRMINGHAM, CARDIFF, DUBLIN, GLASGOW, LEEDS, MANCHESTER, NEWCASTLE-ON-TYNE, SWANSEA, BRADFORD, LIVERPOOL, NOTTINGHAM, NEWCASTLE (STAFFS) BRIGHTON, SOUTHAMPTON, EDINBURGH, BELFAST, BRISTOL.

London Showrooms: 20/22 MOUNT ST, PARK LANE, W.1
TELEPHONE: MAYfair 5671/2

AP82

Another 'first' for Ferranti

Ferranti Ltd. have received an order from the Central Electricity Generating Board through the Northern Project Group for the largest Transformers ever ordered from a manufacturer in this country by a British customer. The placing of this order demonstrates Ferranti's leading position in the Transformer industry. The contract is for two 310,000 kVA, 3 phase, 50 cycle double-wound Transformers for installation at Blyth 'B' Power Station, Northumberland, to step up the Generator voltage to 295 kV and to provide a direct connection to the Super Grid. The units are water-cooled and incorporate all the latest research and developments; they will be equipped with Ferranti Resistor Type On-Load Tap Change Gear.

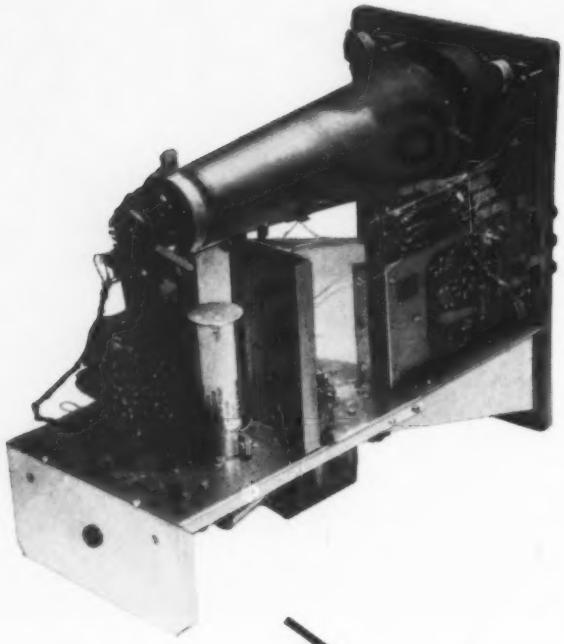
The Consulting Engineers are Merz & McLellan.

FERRANTI *first into the future*

FERRANTI LTD Head Office and Works: HOLLINWOOD · LANCASHIRE Telephone FAllsworth 2000
London Office: KERN HOUSE · 36 KINGSWAY · LONDON W.C.2. Telephone TEMple Bar 6666

FT229/2

with
an eye
to
voltage...



FORMICA* laminates—the finest quality made—
are standard for modern electronic equipment.
For example, the Kit Double-Beam Oscilloscope by *Cossor*
has five printed circuits produced entirely from FORMICA Copper Clad.
One more illustration of FORMICA's place in the electronic
developments of today. All FORMICA
laminates are tested for quality, performance and reliability.

FORMICA LTD

for electrical insulation

Copper clad, paper, fabric and glass laminates. Engraving and printed materials.

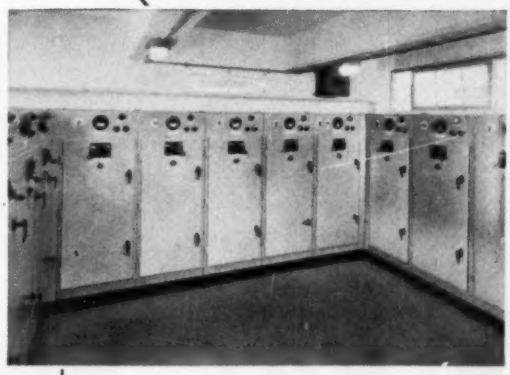
A SUBSIDIARY COMPANY OF THE DE LA RUE COMPANY LTD.
B.J.— DE LA RUE HOUSE, 84/86 REGENT STREET, LONDON W.1.

*FORMICA is a registered trade mark

. . . and leave the rest to GWB Control Gear

The accumulated knowledge and experience gained through the direct application of control gear in their own installations over a considerable number of years has placed G.W.B. in the unique position of having an intimate knowledge of the failings and drawbacks of conventional equipment.

The introduction of G.W.B. Control Gear of the air-break type has made it particularly suitable for long life and the heavy duty conditions found in all branches of modern industry.



Centralised motor control room completely equipped with G.W.B. gear controlling coke conveyor and pump motors, etc., at a large modern gas works. Comprehensive gas production control panels have also been supplied.

GWB

G.W.B. FURNACES LIMITED (CONTROL GEAR DIVISION)

P.O. BOX 4 · DIBDALE WORKS · DUDLEY · WORCS ***Telephone: Dudley 55455 (9 lines)***

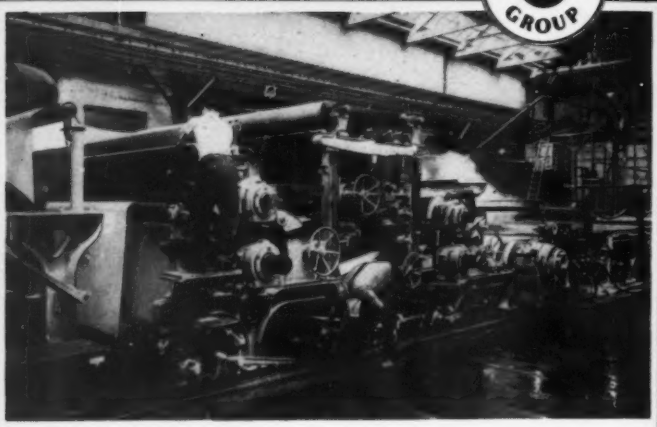
ASSOCIATED WITH: GIBBONS BROS. LTD. AND WILD-BARFIELD ELECTRIC FURNACES LTD.

GWB410

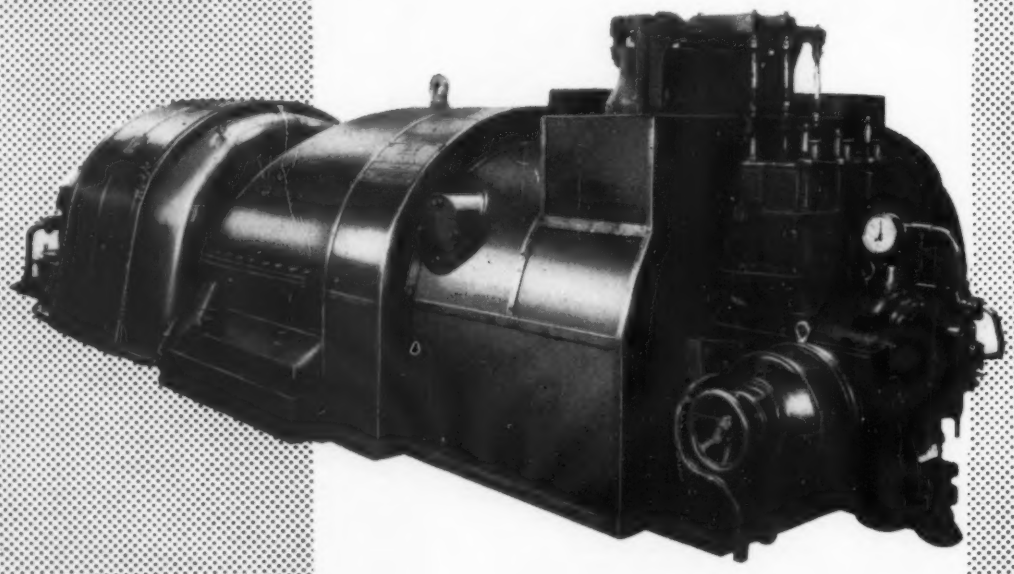
G.E.C. AND THE INVERESK GROUP PAPER MILLS

INVERESK GROUP

ONE GOOD THING LEADS TO TWELVE MORE



A G.E.C. passout condensing turbo-generator was first installed in a paper mill of the Inveresk Group in 1933. Since then twelve further machines of similar type totalling more than 40,000 kW have been installed in other Inveresk mills. The repeated choice of G.E.C. power generating equipment over a period of 25 years by this important and progressive group of paper mills is a demonstration of their satisfaction with the reliability, efficiency and low cost of maintenance of G.E.C. plant.



386

G.E.C. power plant

THE GENERAL ELECTRIC COMPANY LIMITED OF ENGLAND
MAGNET HOUSE, KINGSWAY, LONDON, W.C.2.

G.E.C.

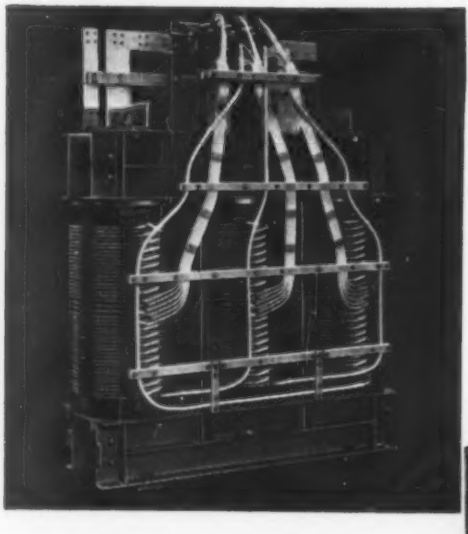
A.S.T.A.Certified **fuse links** H.R.C.

Stocked at all G.E.C. branches

Send for Publication X3730, a handy pocket-size guide to the selection of Industrial Cartridge Fuses

THE GENERAL ELECTRIC CO. LTD., MAGNET HOUSE, KINGSWAY, LONDON, W.C.2

Large — medium — small

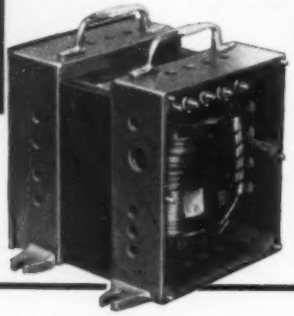


TRANSFORMERS

by Hackbridge

ABOVE: One of three 100 MVA 220 kV type ON transformers for Tasmania.

CENTRE: 1500 kVA distribution transformer for the Far East.



BELOW: Low power multipurpose unit.

23 MILLION KVA IN SERVICE

Send for publications.

HACKBRIDGE AND HEWITTIC ELECTRIC CO. LTD

HERSHAM · WALTON-ON-THAMES · SURREY

Telephone: Walton-on-Thames 28833 (8 lines) Telegrams & Cables: "Electric" Walton-on-Thames

Heatrae of Norwich

present

The most up-to-date

AUTOMATIC ELECTRIC WATER HEATER

Only 10 inches (25·4 centimetres) wide, yet delivering up to 9 gallons (40·9 litres) of hot water per hour, the Heatrae "Express" is ideal for economy use.
The highest standards of British workmanship are evident throughout and never before has such value, performance, style and craftsmanship been embodied in an automatic electric water heater.
An economy electric 'Eye' glows when the current is on and is extinguished when the correct temperature is reached.
The special dispenser outlet ensures smooth even flow and instant cut-off when the valve is closed.
Available in loadings of 3kW or 2kW at 230/250 volts, or 200/220 volts, A.C. only.
Finished cream or white.
U.K. Price: £10. 12. 6. Plus P. Tax: £2. 1. 5.
Full details on leaflet No. 92 sent on request.

Heatrae Lido 'Express'

★ 9

GALLONS of PIPING HOT WATER per hour—every hour!

Manufacturers of Electric Water Heaters, Oil Heaters, Immersion Heaters, Urns, Towel Rails, Airing Cupboard Heaters, Electric Fires, Flameproof Heating Apparatus, Food Trolleys, Warming Plates, Air Heaters. Specialists in Steam Heated Oil Heaters and Calorifiers for Shipboard.

HEATRAE LIMITED

Pioneers since 1920 in all-electric water heaters

NORWICH - ENGLAND

Telegrams: HEATRAE · NORWICH Telephone: NORWICH 25131 (Private Exchange)

HAIR going grey? . . . being torn out by the roots? . . . or just vanishing? Such tonsorial troubles—an occasional occupational hazard with Cable-buyers—are a call to action for Henley's Eager Beavers. Answering every cable call, from 28 strategically placed Henley branches, almost as quickly as it takes to say 'short-back-and-sides', Eager Beavers clip delivery times and achieve hair-raising results and amazing service . . . and the next gent please?

By Appointment to Her Majesty The Queen Electric Cable Manufacturers

HENLEY

Eager Beaver Service

brings you the wiring cables you want . . . WHERE YOU WANT THEM . . . WHEN YOU WANT THEM

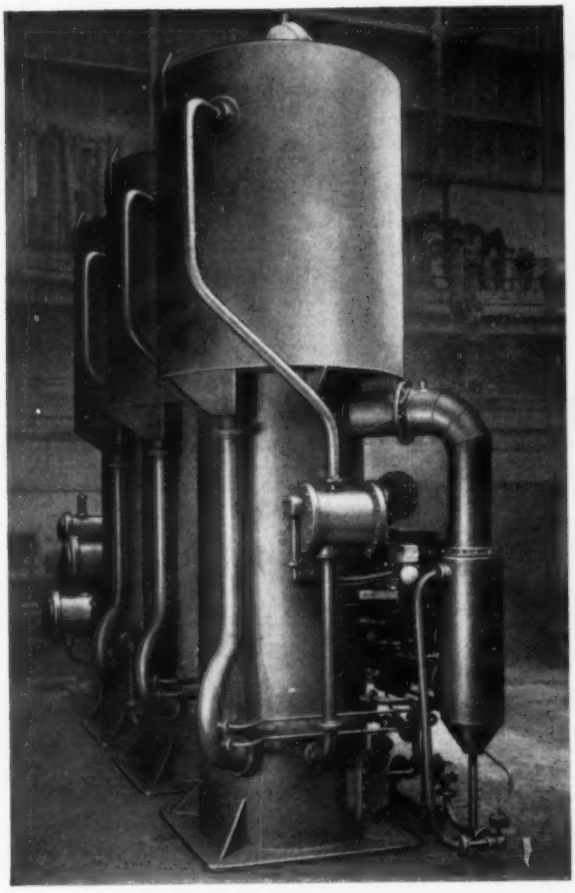
HENLEY WIRING CABLES FROM STOCK

V.R. Braided and Compounded
P.V.C. Insulated only
P.V.C. Insulated and Sheathed
Polythene Insulated and P.V.C. Sheathed
V.R. Insulated Tough Rubber Sheathed
V.R. Insulated Lead Alloy Sheathed
Flexible Cords—Rubber and Plastic

These are but a few of the very wide range of cables and wires we manufacture to cover every electrical need

An A.E.I. Company

W. T. HENLEY'S TELEGRAPH WORKS CO. LTD
51-53 HATTON GARDEN · LONDON · EC1 · Tel: CHAncery 6822



Triple effect re-compression type evaporator for 25,000 lb/hr. feed water

Evaporating Plant

The trend towards higher boiler pressures and temperatures creates a need for greater purity of the feed water. Whilst the bled steam unit evaporator, incorporated in the feed system, is economically the best source of pure water for sets with a fairly steady load factor, independent central evaporating plant (incorporating vapour re-compression for economy) has many advantages, particularly for intermittent operation.

Hick Hargreaves supply bled steam unit evaporators, also vapour re-compression central plants in single, double, or triple effect of capacities up to 40,000 lb/hour (18,000 kgs/hour).

Hick Hargreaves

AND COMPANY LTD · BOLTON

H 152

T172A

Left: *Double-tier stand holding a typical battery of 14 Tudor sealed-type cells as used with 'Safetylyte' emergency lighting equipment.* **Right:** *'Safetylyte' Major charging and control cubicle.*

A mains interruption is the cue for Tudor 'Safetylyte' to play the solo part. It springs automatically into action for instant take-over at split-second notice. The Tudor storage battery included can be kept fully charged for many years at negligible cost and needs little maintenance. Tudor 'Safetylyte' Emergency Lighting Equipment is available in compliance with all Home Office and County Council regulations. It offers complete emergency lighting protection in every type of public building both large and small.

Tudor

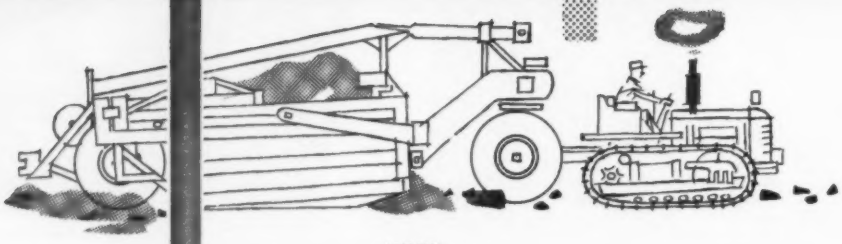
SAFETYLYTE
EMERGENCY LIGHTING

THE D.P. BATTERY CO. LIMITED
MANUFACTURERS OF
KATHANODE AND TUDOR BATTERIES

BAKEWELL, DERBYSHIRE · *Telephone:* BAKEWELL 581-5

The INVICTA range of Electrodes covers arc welding applications, and is in world-wide service throughout the shipbuilding and engineering industries
By choosing a specifically designed INVICTA Electrode, you can be sure of a perfect arc welding job **every** time.

service to industry



'GENWAY' ELECTRODES

High quality, general purpose Electrodes for welding in all positions. Easy manipulation on wide range of joints. Readily removable slag from fillet welds exposes perfectly clean weld metal free from undercut.

'SPEEDWAY' ELECTRODES

Most economical due to fast running at comparatively low currents with very good penetration. Excellent for general engineering work, simple operation and easy slag removal.

APPROVALS.
The Admiralty (All gauges Mild Steel). Ministry of Transport. Lloyds Register of Shipping. (United with British Corporation Register.) Complies with B.S.S. 639/1952.

NORWEGIAN.
Det Norske Veritas — All positions. Also for welding "W" and "WW" quality steels.

INVICTA electrodes

Full details gladly sent on request.

INVICTA ELECTRODES LTD.
Member of the Owen Organisation.

BILSTON LANE, WILLENHALL, STAFFS.
Telephone: James Bridge 3131. Ext. 308

MK 168E DHB

Whether it's a socket-outlet

switchsocket-outlet

pilot-lamp switchsocket-outlet

rated at 2, 5, 13 or 15 amperes

with brass plate finished BMA or matt chrome

or moulded in brown or ivory

whether it's a fused spur-box

with a switch

or a pilot-lamp

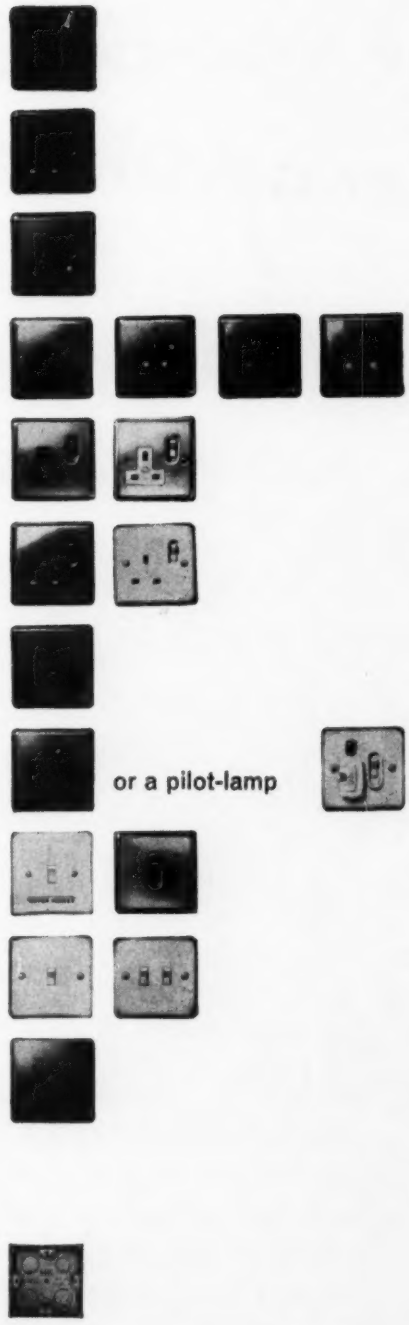
a water-heater switch

a one or two gang Plateswitch

or even a clock connector

MK make a design to fit the

standard box with 2⅜" centres



.....(and all the many 1 and 2 gang MK Gridswitch combinations also have 2⅜" centres)

M. K. ELECTRIC LIMITED
EDMONTON, LONDON, ENGLAND

MK

IF YOU CUT, GOUGE, BEVEL

or GROOVE Metals – THE

Arcair TORCH

will save you money!

Using only an electric arc and compressed air, the Arcair Torch is the new, efficient and money-saving answer to most metal removing problems. Whether used as a production or maintenance tool, the patented Arcair Torch saves up to 60% over other metal removing methods.

For further information on the Arcair Torch and a demonstration of how this money-saving tool can bring economies in YOUR works, please write to:

AA13

LINCOLN ELECTRIC CO. LTD.

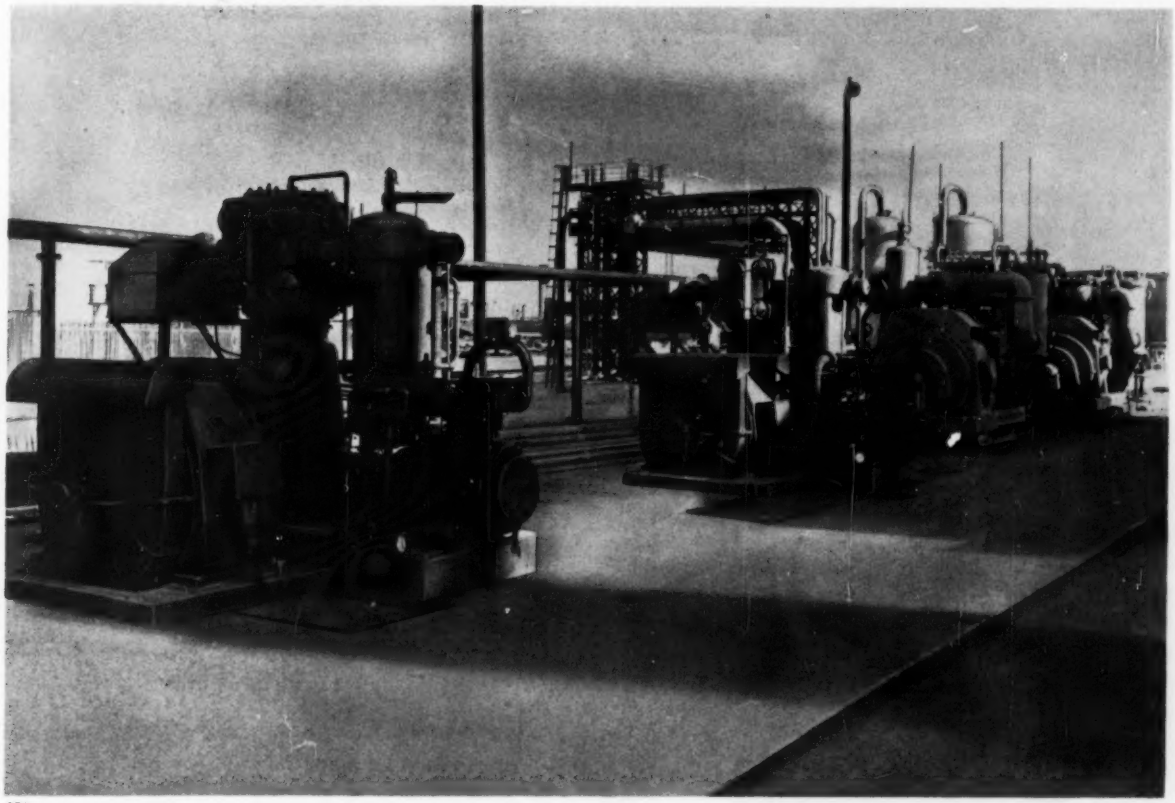
BLACK FAN ROAD · WELWYN GARDEN CITY · HERTS

TELEPHONE: WELWYN GARDEN 920/4 · 4581/5

A MEMBER OF THE GKN GROUP OF COMPANIES

ELECTRIC MOTORS

for all industries and all services



983

Mather & Platt Induction Motors driving compressors at a large Chemical Works. The two in the foreground are 3300 v. double squirrel-cage motors rated at 350 b.h.p. 333/325 r.p.m. The two in the background are ventilated squirrel-cage motors, 3300 v. 325 r.p.m. 435 b.h.p. These four weather-proof motors are direct-on started, taking low starting currents.

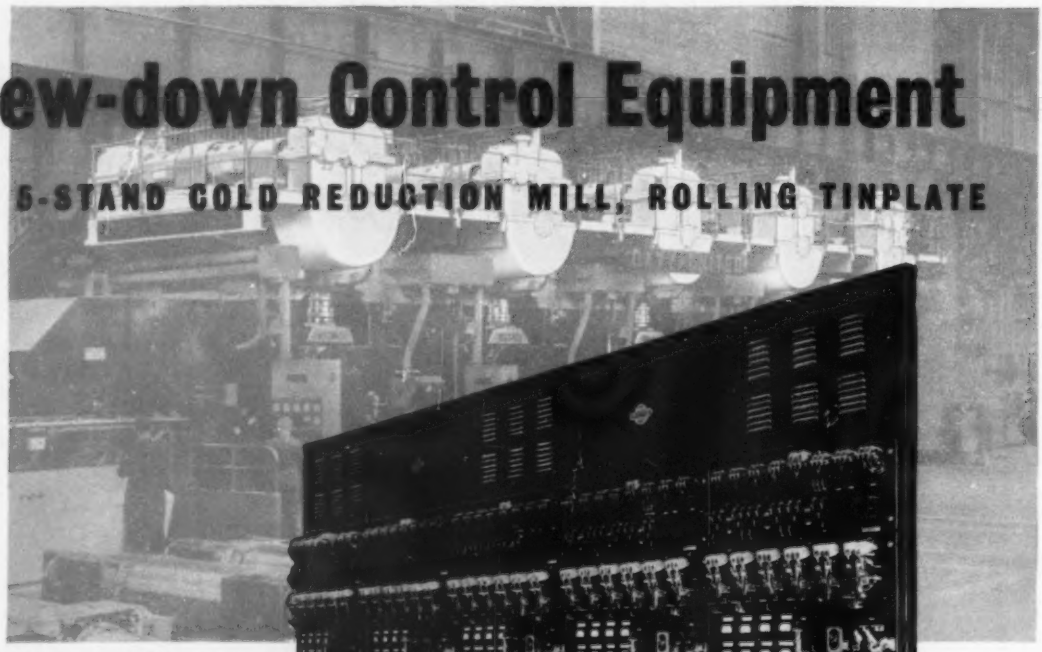
Mather & Platt
LIMITED

PARK WORKS, MANCHESTER, 10

Telephone: COLlyhurst 2321 *Telegrams: Mather, Manchester*

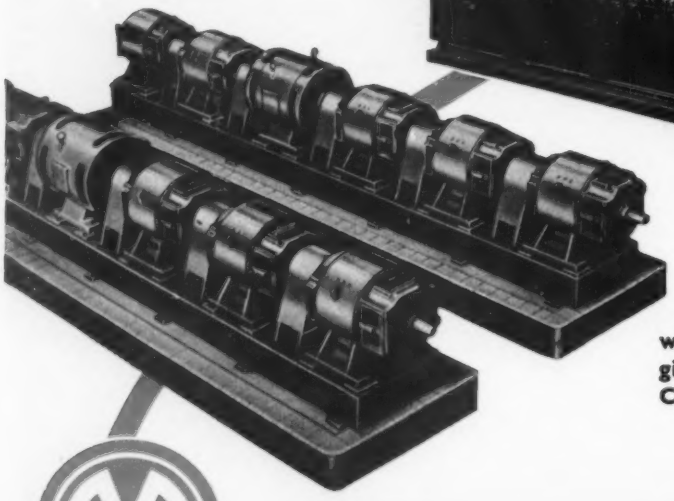
Screw-down Control Equipment

ON 5-STAND COLD REDUCTION MILL, ROLLING TINPLATE



—AT VELINDRE WORKS

Similar Control Supplied for
Temper Mills Numbers 1 & 2



Ward Leonard Sets with 3 Field Generators giving Fast and Accurate Control of Gauge.

Mawdsley's

By Courtesy of The Steel Company of Wales Limited (Tinplate Division)
Consulting Engineers: McLellan & Partners. Switchboards supplied by Igranic Electric Co. Ltd.

MAWDSLEY'S LTD DURSLEY GLOUCESTERSHIRE

Specialists in Specials

TELEPHONE: DURSLEY 2386 (5 LINES) • GRAMS: ZONE, DURSLEY
London Office: 28 Queen Anne's Gate, Westminster, S.W.1. Tel: Whitehall 8892

Some of the equipment used in world wide communication networks. By Courtesy of Cable & Wireless Ltd.

M & I electrical insulating materials are extensively used for specialised applications in communications, control equipment, etc., in electronics and indeed in every branch of electrical engineering — where reliability is so essential.

If you have any problems concerning electrical insulation, we can help you. Our research staff are continually developing materials and processes to meet new requirements and our engineers are always pleased to offer their advice.

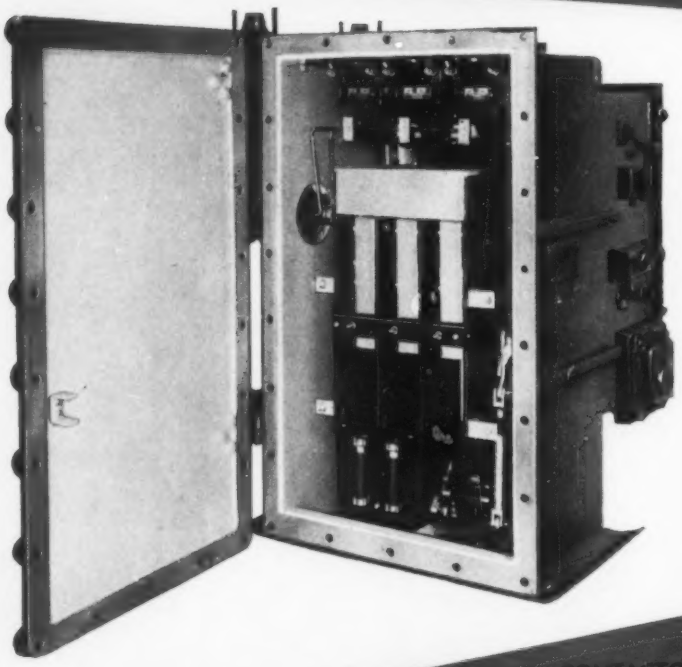
Write for full details of our products and services.

m and i

The Electrical Insulation People

THE MICANITE & INSULATORS CO., LTD.,

WALTHAMSTOW, LONDON, E.17. TELEPHONE: LARKSWOOD 5500. TELEGRAMS: MYTILITE, LONDON, TELEX. TELEX: 25183.



CONTACTOR A.S.T.A.
TESTED TO B.S. 775-1956

FLP

FLAMEPROOF DIRECT-ON STARTER 250 h.p. 3-3 k.v.

M&C

THE FOLLOWING ADDITIONAL FEATURES CAN BE PROVIDED:

Control circuit 110 volt; alternatively, intrinsically safe control circuit.
Earth leakage protection; alternatively, sentryfugue control relay for belt slip protection.
Brake control unit with overcurrent protection.
500 V.A. supply available for external lighting when brake control unit is not included.
Automatic sequence starting.
Ammeter—Voltmeter—H.B.C. Fuses.

3.3 K.V. STARTERS ARE ALSO AVAILABLE IN INDUSTRIAL ENCLOSURES FOR DIRECT-ON AND STATOR/ROTOR STARTING UP TO 250 h.p.

M. & C. SWITCHGEAR LTD.

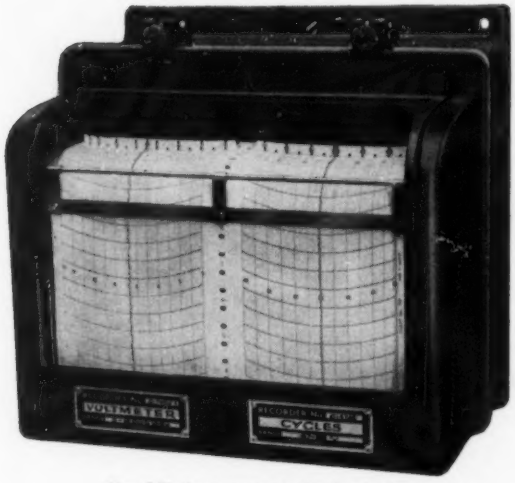
KIRKINTILLOCH, GLASGOW.

LONDON OFFICE, 36 VICTORIA ST., S.W.1. SHEFFIELD OFFICE, OLIVE GROVE RD.

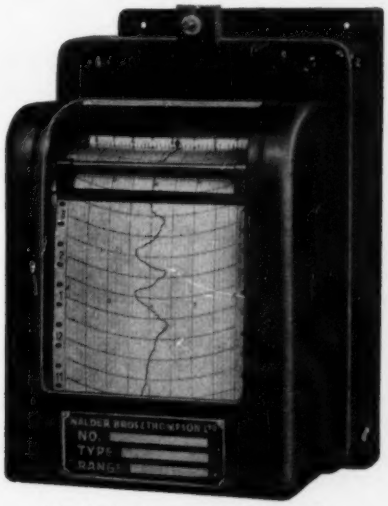
A Complete Range of Graphic Recorders

Single, Double or Triple instruments
all in Flush, Projecting or Portable mountings

AMMETERS
VOLTMETERS
WATTMETERS
FREQUENCY METERS
POWER FACTOR METERS



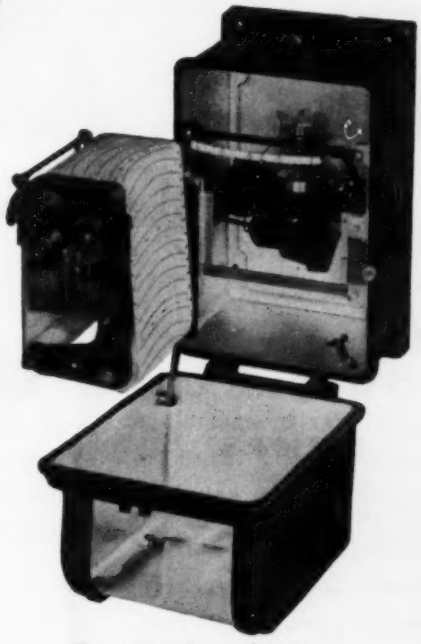
Double instrument (Projecting)



Single instrument (Projecting)

Our improved driving mechanism gives very accurate timing using hand wound or synchronous motor clocks.

Standard Chart Speed—1 inch per hour (a 65 foot roll lasts for a whole month). Multi-speed charts can also be supplied.



Easy access for recharting

Check List of Nalders Products

Ammeters Voltmeters	Power Factor meters Electrostatic voltmeters
Wattmeters Vectormeters	Phase Sequence indicators Contact-making instruments
Synchroscopes Frequency meters Graphic Recorders	Numerous Protective Relays Miniature Circuit-Breakers Earth Proving Supply Switches
Controller Mountings Hoseproof Flameproof or Standard **Also** Portable Instruments	**Switchboard Mountings** (Flush and Projecting) Square or Round in Pressed Steel or Aluminium **Also** Sector Edgewise and Hermetically Sealed

For Technical Pamphlets, *of any of our products, please telephone or write*

Nalder Bros & Thompson Ltd

ELECTRICAL INSTRUMENTS

ESTABLISHED IN LONDON IN 1884

Dalston Lane Works London E.8

'Phone **CLI**ssold **2365** 'Grams Occlude Hack London

HEENAN

CLOSED CIRCUIT

AIR COOLERS

for ventilation of turbo-alternators
Lengthy experience in practical design
Wide variety of ducting and damper layouts
Highly efficient cooling surfaces
Heavy and robust construction
Special attention to ease of access and maintenance

FORCED DRAUGHT

WATER COOLERS

for cooling circulating water of Diesel, Gas and Petrol Engines, Refrigerating Condensers, Air Compressors, Liquid Controllers, Process Works, etc.
Save 95% of water otherwise wasted
Robust and compact all-metal construction
Install in- or out-of-doors

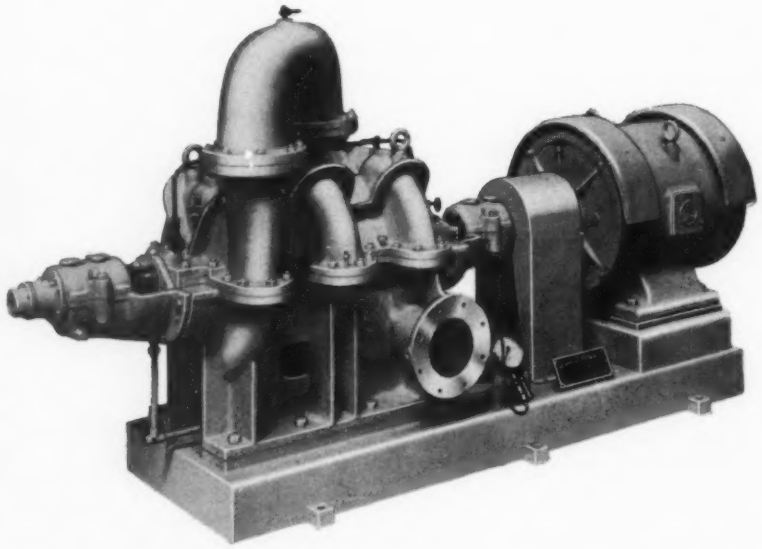
H&F

HEENAN & FROUDE LTD : WORCESTER : ENGLAND

'Mirrlees'

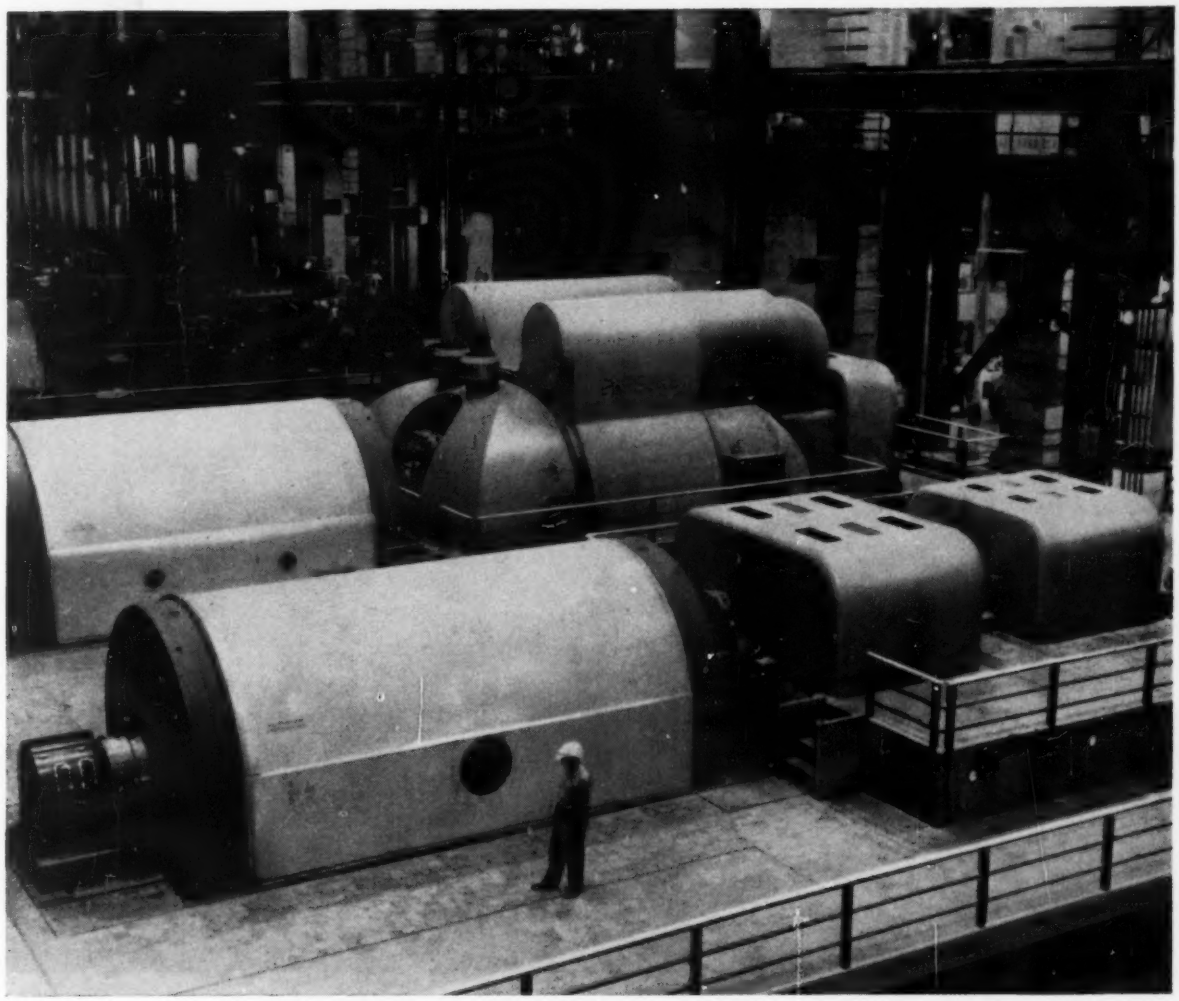
CONDENSATE PUMPS

Three-Stage Condensate Extraction Pump for Mirrlees Surface Condensing Plants. Duty 800 g.p.m. to Total Head of 230 ft.



THE MIRRLEES WATSON CO LTD

Scotland Street, Glasgow, C5
London Office: 38 Grosvenor Gardens, SW1



the largest turbo-generator

now in service in the British Commonwealth

Other PARSONS GIANTS under construction are:–

200,000 kW Two for Central Electricity Generating Board, England.

300,000 kW Two for Hydro Electric Power Commission of Ontario, Canada.

500,000 kW for Tennessee Valley Authority, U.S.A.

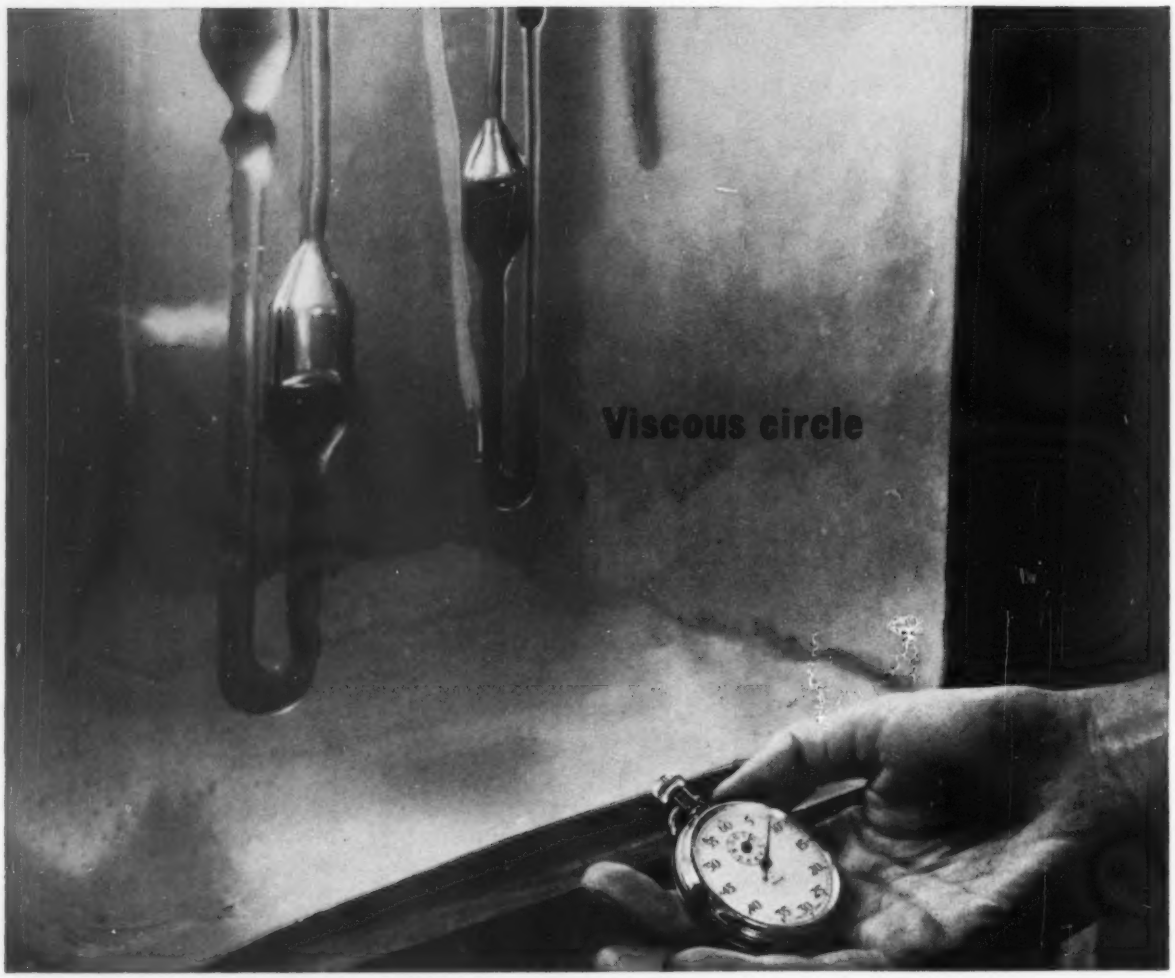
550,000 kW for Central Electricity Generating Board, England.

(The LARGEST MACHINE under construction or in service in THE WORLD)

Housed in the Richard L. Hearn Generating Station of the Hydro Electric Power Commission of Ontario is the largest turbo-generator in service in the British Commonwealth. This huge 200,000 kilowatt machine is one of four PARSONS cross-compound turbo-generators built for this power station.

PARSONS

C. A. PARSONS & COMPANY LIMITED
HEATON WORKS · NEWCASTLE UPON TYNE 6



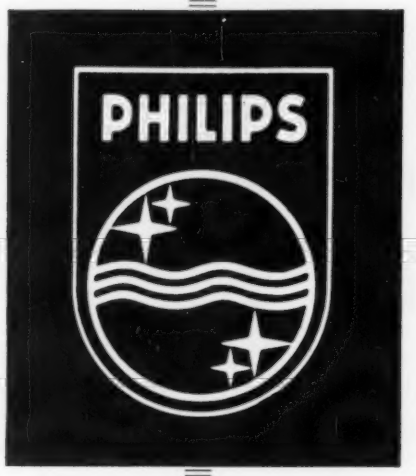
IN THE LAB: New batch of resin. Let's have a sample. Down the viscometer-tube with it. Watch the upper mark. Start stop watch . . . NOW. Time for this formulation? 240 secs. ±1/5 sec. Reaching lower mark . . . NOW. 240 secs. dead. O.K. Pass batch to works.

IN THE WORKS: Stacks of veneers. Resin impregnated. Ready for heating and pressing in 4500-ton press. To be turned into Permali. Pressure and temperature are critical. Both therefore closely controlled. And recorded under process controller's supervision. BUT all this care is wasted if veneers are not fully impregnated. Means having resin-viscosity right to start with. That's why Permali sample every batch of resin before delivery to works.

PERMALI Insulation

Totally tested.....most reliable

PERMALI LIMITED GLOUCESTER ENGLAND TEL: 24941



This emblem guides the choice of millions

Radio & Television Receivers.
Radiograms & Record Players.
Gramophone Records.
Tungsten, Fluorescent, Blended and
Discharge Lamps & Lighting Equipment.
'Philishave' Electric Dry Shavers.
'Photoflux' Flash Bulbs.
High-Frequency Heating Generators.
X-ray Equipment for all purposes.
Electro-Medical Apparatus.
Electrically-heated Blankets.
Heat Therapy Apparatus.
Arc & Resistance Welding
Plant and Electrodes.
Electronic Measuring Instruments.
Magnetic Filters.
Battery Chargers and Rectifiers.
Sound Amplifying Installations.
Cinema Projectors.
Tape Recorders.
Hi-Fi Equipment.
Health Lamps.
Hearing Aids.

PHILIPS ELECTRICAL LTD • CENTURY HOUSE • SHAFTESBURY AVE • LONDON W.C.2

(P1036)

Magnet frame for 4,000 h.p. Mill Motor treated with P.J. Black Sealing and Finishing Varnish
By kind permission of
General Electric Co. Ltd., Birmingham

Additions are continually made to our range of specialised insulating varnishes and electrical machinery finishes. Recent research has largely been concerned with exploiting the latest synthetic resins, and many new formulations with characteristics of considerable interest to the electrical industry have been evolved in our laboratories. Requests for further information, or specific enquiries regarding insulating problems, should be addressed to our Insulating Varnish Department.

STOVING VARNISHES
(Natural Resin Type) (Synthetic Resin Type)
THERMO-SETTING VARNISHES · SOLVENTLESS VARNISHES
AIR-DRYING VARNISHES · CLOTH VARNISHES
CORE-PLATE VARNISHES (Stoving and Air Drying)
COPPER WIRE ENAMELS (Oleo-resinous and Synthetic Types)
All the above are supplied in black and clear.

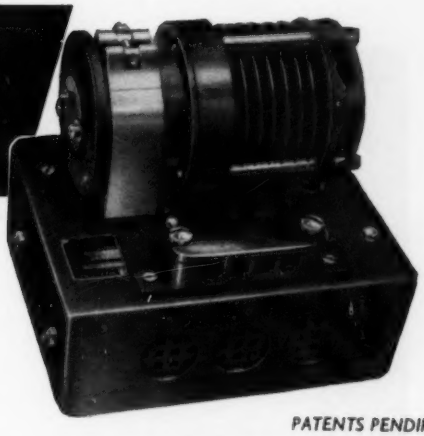
ACID AND HEAT RESISTING ENAMELS. *Available in all colours.*
MICA BONDING VARNISHES · COIL STICKING VARNISHES
SLEEVING VARNISHES (Black, Clear and Colours)
CABLE LACQUERS (Non-flam., Cellulose Type and P.V.C.)
COMPOUNDS (Various Types)
All the materials listed conform to B.S. Specifications wherever applicable.

PINCHIN, JOHNSON & COMPANY

4 CARLTON GARDENS · LONDON · S.W.1 · TELEPHONE TRAFALGAR 5600

Branches: Belfast, Birmingham, Bootle, Brighton, Bristol, Glasgow, Leeds, Manchester, Newcastle-on-Tyne & Southampton

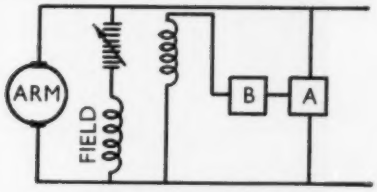
TRANSISTORISED AUTOMATIC VOLTAGE REGULATORS



Model shown is for the control of a 28 Volt D.C. generator for use on aircraft.

Regulation closer than ± 1% between extremes of temperature from −60°C to + 70°C
Speed of response 50/60 milliseconds.
For industrial purposes at normal ambient temperatures regulation within ± 0·5%.
Dimensions 5" × 6" × 5½" high.
Weight 4 lbs.

PATENTS PENDING



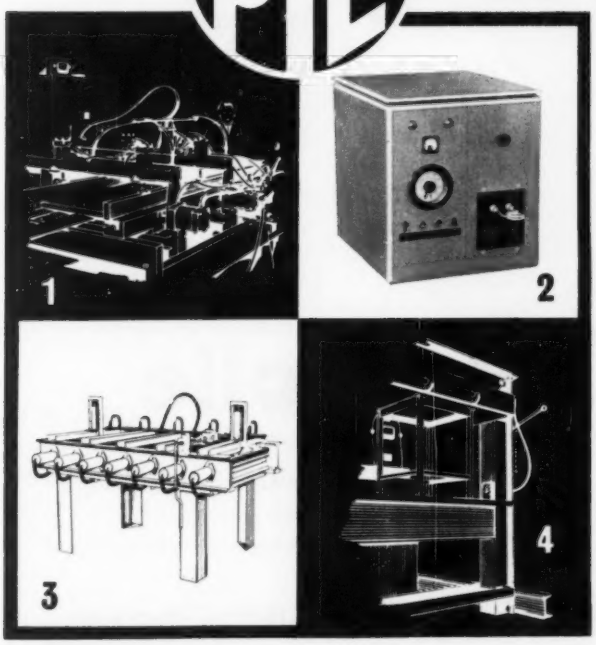
A = REFERENCE BRIDGE
B = TRANSISTOR AMPLIFIER

NEWTON DERBY

NEWTON BROS (DERBY) LTD
ALFRETON ROAD · DERBY
Phone: Derby 47676 (4 lines) *GRAMS: DYNAMO · DERBY*
London Office: IMPERIAL BUILDINGS, 56 KINGSWAY, W.C.2

Manufacture a full range of

PROCESS HEATING EQUIPMENT



R.F. heating is the most efficient method of gluing wood to wood or plastic, and Pye provide a truly comprehensive service in this field. Whether your production is large or small, there are Pye generators and Pye-Gibbs presses to help you produce more quickly, more cheaply and with a great saving in unproductive curing space. We offer free technical advice on all problems concerning gluing in woodworking and allied industries—just fill in the coupon for further details, or write to the address below.

1 RF STRAY-FIELD PLATEN
Designed for RF Heating without elaborate jigs.

2 INDUCTION HEATER
The RF 1/2 Heating Unit, Nominal power output, 3 kw.

3 RF LIPPING JIG
Designed for edge lipping of Flush Doors and Chipboard.

4 RF EDGE JOINTING PRESS
Designed for the edge-to-edge bonding of boards.

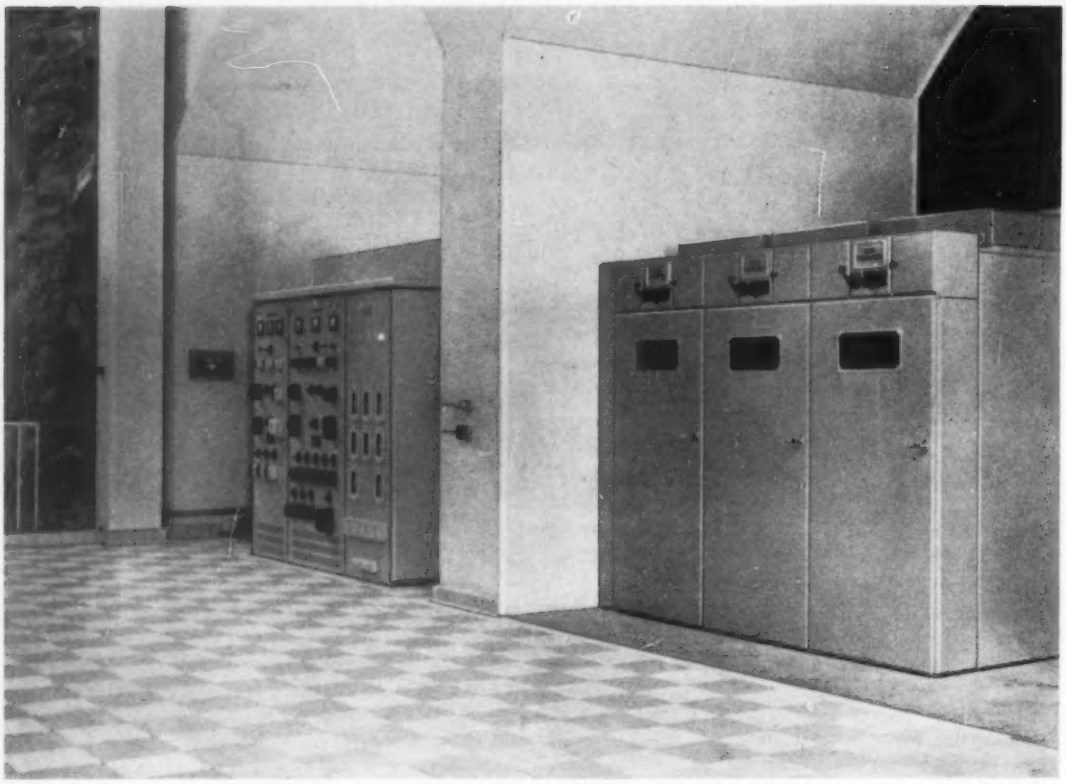
To: Pye Ltd., Process Heating Division, 28 James Street, Cambridge.
Please send me details of Pye Process Heating Equipment.

NAME .....

COMPANY .....

ADDRESS ..... BJ 10

PYE LIMITED OF CAMBRIDGE



St. Fillans Power Station. Consulting Engineers: Messrs. Kennedy & Donkin. Photograph by courtesy of The North of Scotland Hydro-Electric Board

The First

11-kV 500-MVA

air-break

circuit-breakers

have now been

in continuous service

for almost

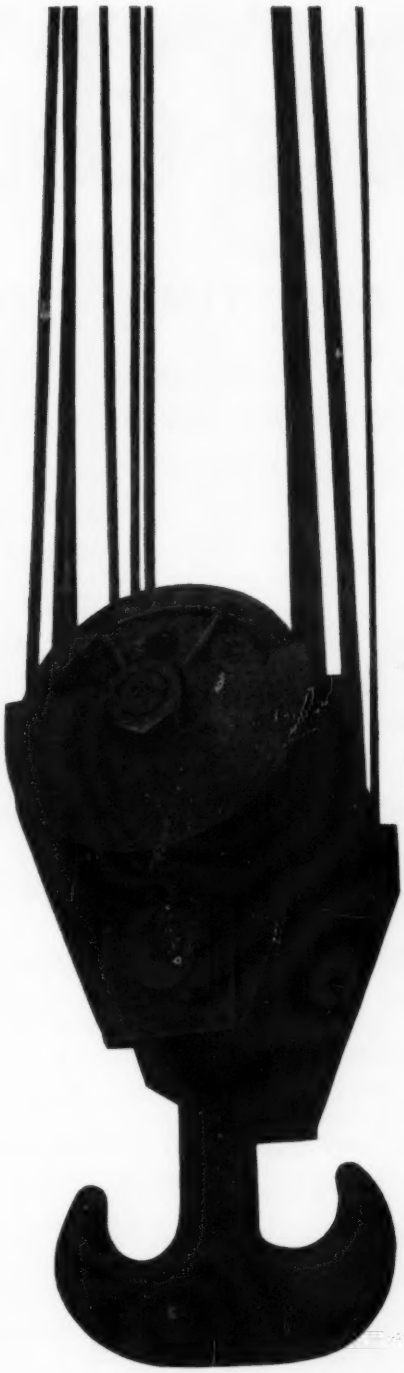
two years

Air-break switchgear controlling the main plant at St. Fillans is also widely used for Power-station auxiliaries

Reyrolle

A. REYROLLE & COMPANY LIMITED - HEBBURN - COUNTY DURHAM - ENGLAND

TO LIFT THE LARGEST ALTERNATORS YET ENVISAGED



The hook of the 175 ton 'traveller' in our new turbine shop at Hartlepool. Here we can build, to Brown Boveri design, the largest turbo-alternators yet envisaged. At Hartlepool we, of course, also build small turbines, and many other things besides: industrial turbo-alternators down to 500 kW, gas turbines, axial and centrifugal blowers and exhausters, water-tube boilers of Foster-Wheeler design, Economic type boilers, feed heaters, condensers, rotary cooling-water strainers, etc . . . in fact all the major equipment of a power station.

R W G

RICHARDSONS WESTGARTH (HARTLEPOOL) LTD.

A member of **THE RICHARDSONS WESTGARTH GROUP** which co-ordinates the land and marine activities of:

THE NORTH EASTERN MARINE ENGINEERING CO. LTD. — RICHARDSONS WESTGARTH (HARTLEPOOL) LTD.

PARSONS MARINE TURBINE CO. LTD. — THE HUMBER GRAVING DOCK & ENGINEERING CO. LTD.

GEORGE CLARK & NORTH EASTERN MARINE (SUNDERLAND) LTD. — RICHARDSONS WESTGARTH ATOMIC LTD.

ASSOCIATED COMPANY: ATOMIC POWER CONSTRUCTIONS LTD.

RICHARDSONS WESTGARTH (Hartlepool) LTD., HARTLEPOOL, CO. DURHAM

and at 58 Victoria Street, London, S.W.1. 59 Mosley Street, Manchester, 2. 75 Buchanan Street, Glasgow, C.1

sangamo

METERS AND TIME SWITCHES

SINGLE PHASE AND POLYPHASE WATTHOUR METERS

SYNCHRONOUS TIME SWITCHES

SYNCHRONOUS MOTORS AND MOTOR UNITS

*

weston

ELECTRICAL MEASURING INSTRUMENTS

PANEL & SWITCHBOARD INSTRUMENTS

D.C. Moving Coil, A.C. Rectifier, H.F. Thermocouple, A.C./D.C. Moving Iron

PORTABLE INSTRUMENTS

D.C. Moving Coil, A.C. Rectifier, H.F. Thermocouple, A.C./D.C. Moving Iron, A.C./D.C. Dynamometer

LABORATORY STANDARD INSTRUMENTS

D.C. Moving Coil, A.C./D.C. Dynamometer

CURRENT TRANSFORMERS • FREQUENCY METERS • ALL-PURPOSE TEST SETS

AIRCRAFT INSTRUMENTS • RATIOMETERS • TACHOMETERS

ELECTRICAL THERMOMETERS • WESTON STANDARD CELLS

'PHOTRONIC' PHOTO ELECTRIC CELLS • PHOTOMETERS

*

SANGAMO WESTON LTD. ENFIELD · MIDDLESEX

Telephone: ENField 3434 (6 lines) and 1242 (6 lines). Grams: Sanwest, Enfield. Scottish Factory: Port Glasgow, Renfrewshire, Port Glasgow 41151

Branches: London, CHAncery 4971 · Glasgow, Central 6208 · Manchester, Central 7904 · Newcastle-on-Tyne, Newcastle 26867 Leeds, Leeds 30867 · Liverpool, Central 0230 · Wolverhampton, Wolverhampton 21912 · Nottingham, Nottingham 42403 Bristol, Bristol 21781 · Southampton, Southampton 25328.

SANGAMO WESTON

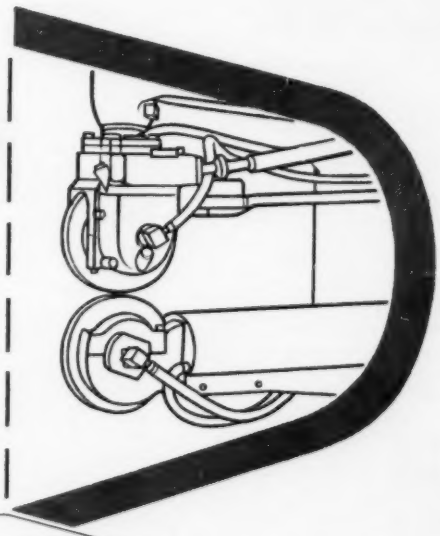
SW/54

Modernise your workshop and reduce costs!

USE DUAL PURPOSE SEAM WELDERS

- All welded construction for strength and rigidity.
- Water-cooling throughout.
- All Electrode Bearings of Special Copper Alloy.
- Simple Layout of Transformer and ancillary apparatus for Easy Maintenance.
- Wide Range of Current and Pressure Adjustment with hand control.
- All Machines can be used with Modulators or with full Electronic Control.

One machine only required for long and end seams. To change-over, the upper electrode is merely turned through 90 deg. and the lower electrode holder replaced; the whole operation takes 20 minutes.



Type W S 6 U
Type W S 7 U
Type W S 8 U

Siemens-Schuckert (Great Britain) Ltd

DEPT S91

FARADAY WORKS · GREAT WEST ROAD · BRENTFORD · MIDDLESEX

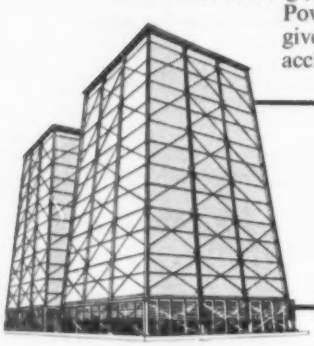
TELEPHONE: ISLEWORTH 2311 TELEGRAMS: SIEMENSDYN, BRENTFORD, HOUNSLOW. TELEX NO. 25337
BIRMINGHAM: TEL. MIDLAND 2082 CARDIFF: TEL. CARDIFF 72094 GLASGOW: TEL. CENTRAL 2635
MANCHESTER: TEL. ALTRINCHAM 5291 NEWCASTLE: TEL. WALLSEND 68301 SHEFFIELD: TEL. 61561

Smee's 591

WHEN IT'S A QUESTION OF COOLING

Undoubtedly, the answer to all air and hydrogen cooling problems is PREMIER. PREMIER closed circuit coolers, among the most highly efficient and economical in the world, are installed in such important power stations as Meaford, Poole, Uskmouth, Hams Hall " C," Darlington, Bold " B," Stockport and Johannesburg ; and hydrogen coolers and heat exchangers are in hand for Hunterston Atomic Power Station. PREMIER design and erect the plants, guarantee the performance and give a 100 per cent. aftersales service. Undoubtedly, PREMIER Coolers are acclaimed by engineers everywhere.

If you have an air or hydrogen cooling problem, write to us—our advice is at your service.



PREMIER
COOLING TOWERS

WE *do the designing ourselves*
WE *manufacture our own plants*
WE *erect the plants ourselves*
WE *guarantee the performance*

The PREMIER COOLER AND ENGINEERING CO. LTD., Shalford, Nr. Guildford, Surrey

---

NEW INDUCTION HEATERS.

IH.64

Redifon

introduce a NEW RANGE
of unusually small, low cost,
1 KW Induction Heaters

IH.64 M

For use in multi-turn coil applications such as brazing, soldering, hardening and annealing.

IH.64 L

For similar applications but suitable for single turn inductors where concentration of power is required without the use of current transformers.

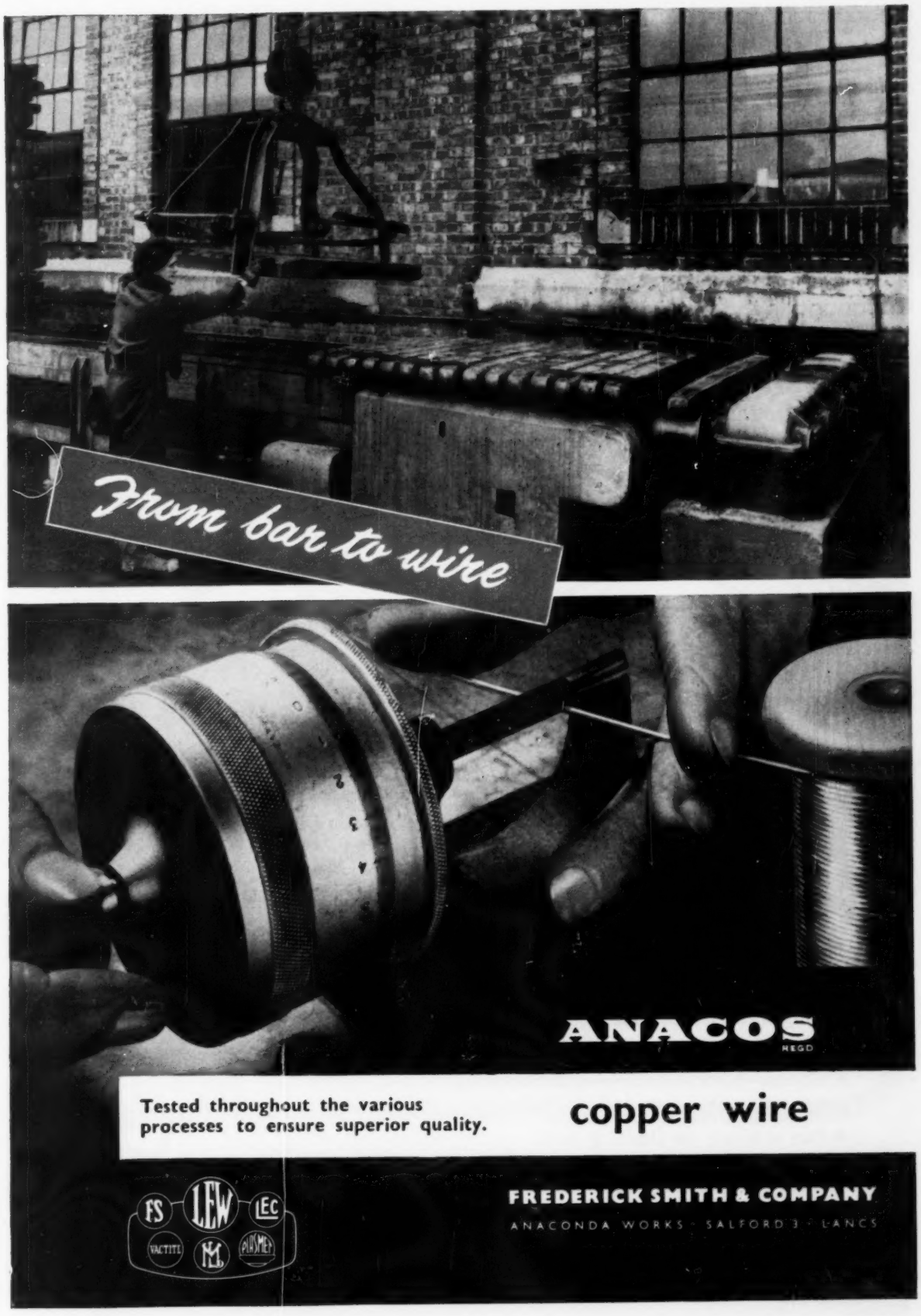
IH.64 H

For operations remote from the generator, power being conveyed by flexible leads. Especially suitable for getter firing and out-gassing of valves and cathode ray tubes.

For full details, please contact

REDIFON LIMITED Industrial Electronics Division, Broomhill Road, London, S.W.18. Tel: VANdyke 7281

A Manufacturing Company in the Rediffusion Group



Tested throughout the various processes to ensure superior quality.

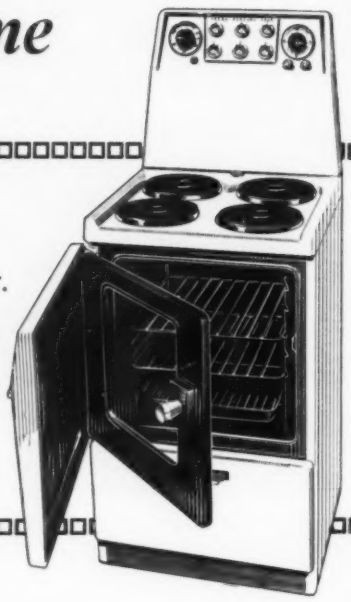
copper wire

FS LEW LEC VACTITE PLASMEC

FREDERICK SMITH & COMPANY

ANACONDA WORKS · SALFORD 3 · LANCS

Creda *makers of so many fine things for the home*



CREDA MERCURY FOUR

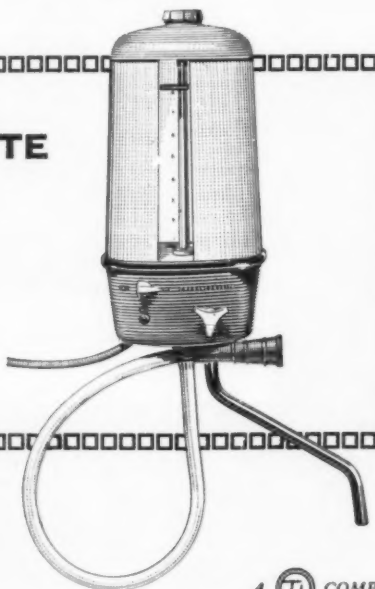
The electric cooker that's more advanced than ever.

- ✳ A new luxury cooker with *four* Creda Quick-Discs which give fastest hob service ever.
- ✳ Easy wipe-over cleaning—Timer Control—inner glass door to large oven—large grill—superb appearance.

THE FAMOUS CREDA DEBONAIR

Britain's first and finest spindryer.

- ✳ Dries clothes ready for *immediate* ironing in 4 minutes or less
- ✳ Gentle with woollens and flimsies ✳ safety lid lock
- ✳ mobile as a tea trolley ✳ takes full family wash.



THE CREDA CORVETTE

The new kitchen appliance that gives tepid, hot or boiling water at the touch of a switch.

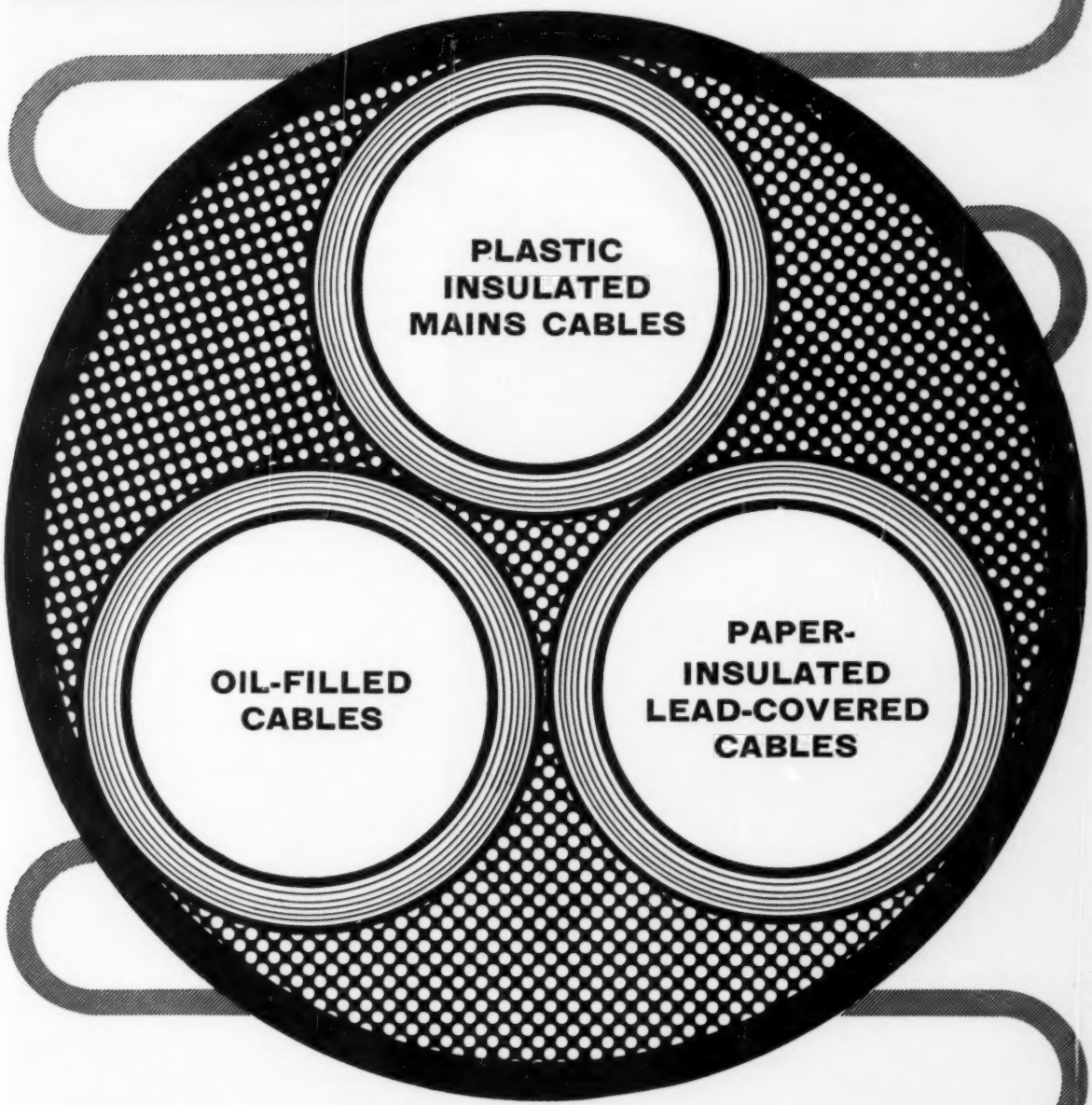
- ✳ Fast—boils a pint in under 2 minutes.
- ✳ Efficient—heats to the temperature you select.
- ✳ Economical—heats exact amount of water required.
- ✳ Easy to install—no plumbing costs.

SIMPLEX ELECTRIC CO. LTD.

Creda Works, Blythe Bridge, Stoke-on-Trent.
LONDON SHOWROOMS: Creda House, 26-28, Binney Street, W.1.
CC700/CO578

A TI COMPANY

Standard



CABLE
AND WIRE
GROUP

Standard Telephones and Cables Limited

Registered Office : Connaught House, Aldwych, London, W.C.2

POWER LINE DIVISION · NORTH WOOLWICH · LONDON, E.16 Telephone : Albert Dock 1401

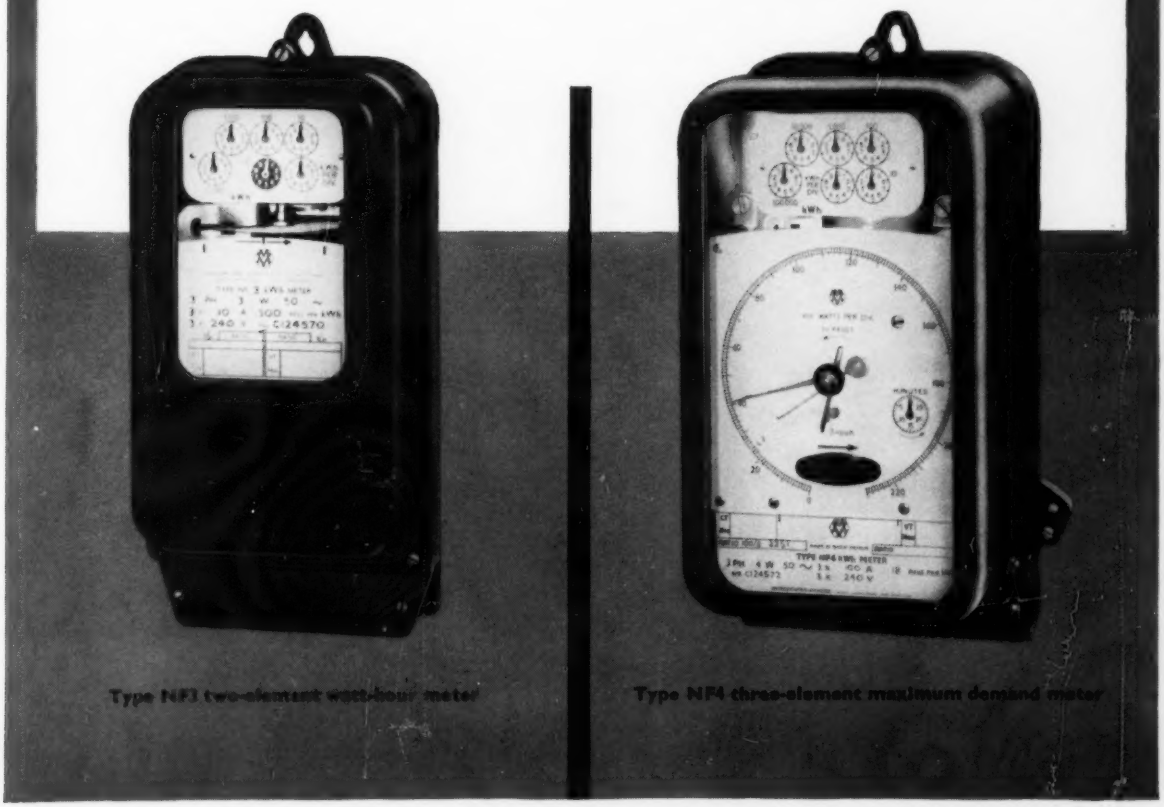
in the air . . .
on the ground . . .
on the sea . . .
Sterling Insulating Varnishes are used throughout the world to protect every type of electrical component operating under all climatic conditions. Wherever you are, whatever the job, if yours is an electrical insulating problem contact STERLING whose advice incurs no obligation.
MADE BY CHEMISTS
Sterling
INSULATING VARNISHES
SERVICED BY ENGINEERS
STERLING INSULATING VARNISHES
are used throughout the world!
STERLING VARNISH CO. LTD. FRASER ROAD TRAFFORD PARK MANCHESTER 17
Telephone: Trafford Park 0282 (4 lines)
Telegrams: 'Dielectric Manchester'
London Office and Warehouse: 6, London Road, Brentford, Middlesex.
Telephone: Isleworth 8133/4
dm ST 21

Printed for the Proprietors, The British Electrical and Allied Manufacturers' Association (Incorporated), by Williams, Lea & Co., Ltd., Clifton House, Worship Street, London, E.C.2.

Accent on Accuracy

WITH THE TYPE NF SERIES

The type NF3 (two-element) and NF4 (three-element) watt-hour and maximum demand meters have been designed to meet present day requirements for overall accuracy. Their easily accessible adjustments, lightweight construction and handsome appearance, will commend themselves to all users. The meters comply in all respects with British Standard 37: Part 4: 1954 and Part 5: 1955.



Type NF3 two-element watt-hour meter

Type NF4 three-element maximum demand meter

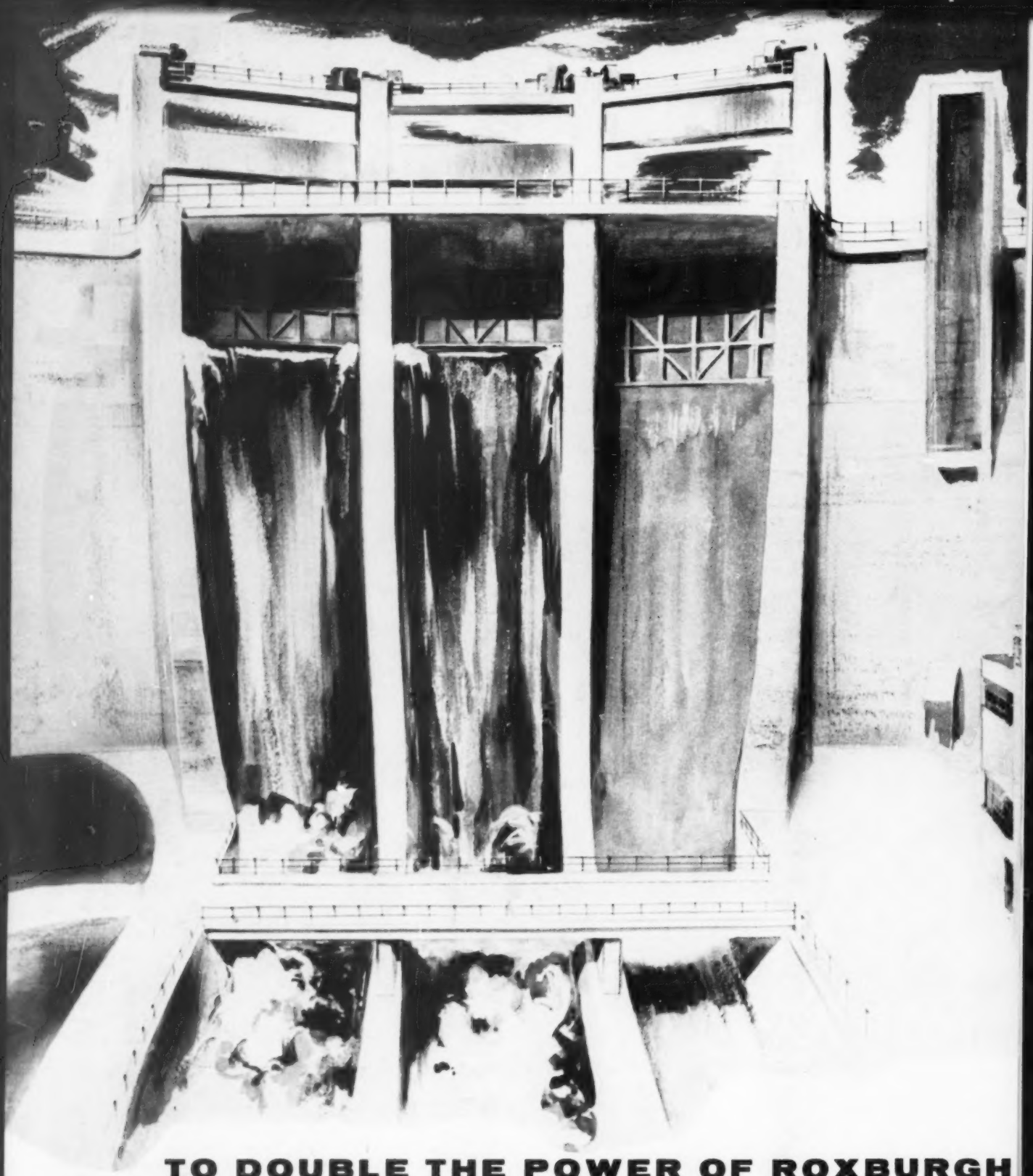
For further information please write for 'The Art of Metering', which gives full details of these meters.

METROPOLITAN-VICKERS
ELECTRICAL CO. LTD. · TRAFFORD PARK · MANCHESTER 17

An A.E.I. Company

LEADING METERING PROGRESS

G/A 801



TO DOUBLE THE POWER OF ROXBURGH

AEI

Four AEI waterwheel alternators at the New Zealand Electricity Department's Roxburgh Power Station are already feeding 160,000 kW into the South Island grid. Four additional sets, to bring the station up to its designed capacity of 320,000 kW, are now in course of construction.

ASSOCIATED ELECTRICAL INDUSTRIES LIMITED

HEAVY PLANT DIVISION — RUGBY AND MANCHESTER, ENGLAND

A5379